

**UNITED STATES DEPARTMENT OF AGRICULTURE  
BUREAU OF CHEMISTRY AND SOILS**

*In cooperation with the University of California Agricultural Experiment Station*

**SOIL SURVEY  
THE COACHELLA VALLEY AREA  
CALIFORNIA**

**BY**

**A. E. KOCHER, in Charge, and W. G. HARPER**

Beginning with the 1923 Series, Soil Survey Reports will be issued separately. These reports of the individual areas will be sent to libraries as soon as they are available and should be filed, preserved, and ultimately bound to take the place of the bound volumes of the Field Operations which have previously been supplied by the department. The reports for each year will be consecutively numbered, the last report for a particular year bearing the conspicuous notice: "This number is the final and last Soil Survey Report for the Year 192-."



**UNITED STATES  
GOVERNMENT PRINTING OFFICE  
WASHINGTON**

**1928**

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[PUBLIC RESOLUTION—No. 9.]

JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:*

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided*, That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]



# SOIL SURVEY OF THE COACHELLA VALLEY AREA CALIFORNIA

By A. E. KOCHER, in Charge, and W. G. HARPER

## DESCRIPTION OF THE AREA

The Coachella Valley is situated in the south-central part of Riverside County, in the southern part of California. Indio, near the center of the valley, is 130 miles southeast of Los Angeles and about 90 miles northwest of Calexico, on the Mexican boundary. The valley is bounded on the north and east by the San Bernardino and Chocolate ranges of mountains, with a number of semidetached intervening ranges known locally as the Little San Bernardino Mountains, Cottonwood Mountains, Eagle Mountains, Orocopia Mountains, and the Mecca Hills. It is bounded on the southeast by desert lands and the Salton Sea, and on the south and west by the Santa Rosa and San Jacinto Mountains. The valley is a relatively narrow area extending about 60 miles northwest from the Salton Sea to the summit of the San Geronio Pass. On the south it is separated from the Imperial Valley by the Salton Sea. The area contains 344 square miles, or 220,160 acres.



FIG. 16.—Sketch map showing location of the Coachella Valley area, California

The Coachella Valley and the broad Imperial Valley to the south of the Salton Sea form a single physiographic basin of triangular outline inclosed on three sides by barren, rugged mountains. Before the present period of extensive reclamation by irrigation, it was known as the Colorado Desert, and the lower part, now occupied by the Salton Sea, was designated the Salton Sink. This basin, which is physiographically continuous with the Gulf of California, has been cut off from the gulf by the low broad delta of the Colorado River.

It is probable that the river flowed alternately into the gulf and into the northern part of the basin, into which it carried and deposited enormous quantities of sediment. Previous to settlement of the region the basin had been dry for an unknown period of time, leaving an area of 2,000 square miles of dry land lying below sea level. In 1905, through erosion of restraining levees and irrigation works below the international boundary constructed in connection with the irrigation system furnishing water to the Imperial Valley, it broke into the basin and submerged about 291,000 acres,<sup>1</sup> forming the present Salton Sea. Since that date the water has been evaporating rapidly, the shore line in the area surveyed having receded 1 to 5 miles. At the present time the surface of the Salton Sea is about 250

<sup>1</sup> Water Supply Paper 395, Colorado River and its Utilization, by E. C. La Rue, U. S. Geological Survey.

feet below sea level and is nearly stationary, as the increment of waste water and drainage from the irrigated areas largely compensates for the annual evaporation.

The area surveyed includes only the southern part of the Coachella Valley. Its boundaries roughly parallel the base of the bordering mountains and have been drawn to include a strip 1 to 3 miles wide marginal to the possible agricultural lands of the valley.

The survey covers about the same area as that included in the earlier soil survey of the Indio area,<sup>2</sup> but the land area is somewhat less extensive owing to the submergence of part of the area of the earlier survey by the Salton Sea.

The present survey includes the valley floor and the alluvial fans or foothill slopes leading up to the mountains. The surface of the lower part of the valley is very uniform, with a gradual fall of about 20 feet to the mile toward the center of the valley and the Salton Sea. Adjacent to the Salton Sea, the surface is comparatively flat. The elevation of the valley floor ranges from about 100 feet above sea level to 250 feet below. A number of square miles in the northwestern part of the area, as well as along the east and west sides, have a billowy or dunelike topography due to wind-blown sands. The dunes vary from 3 to 30 feet or more in height.

The gravelly and stony slopes bordering the east and west sides of the valley slope upward to the base of the mountains at the rate of 100 to 200 or more feet to the mile, the grade increasing rapidly along their upper margins. They are traversed by many dry washes which carry water only after severe storms in the mountains. The topography near the washes is irregular, although along the lower courses the fans widen out, the channels separate and become more shallow, and the surface is more favorable for irrigation. The greater part of the steeply sloping land, however, lies above the proposed location of the "All-American Canal" and in addition is too stony and porous for agricultural use. Beyond the stony fans on the west side of the valley, granitic mountains rise abruptly to elevations of 5,000 to 6,000 feet. At the northwest end of the valley the range is dominated by San Jacinto Peak with an elevation of 10,805 feet above sea level. East of the valley the mountains are somewhat lower and less precipitous. All of the towns and nearly all of the developments in the area are below sea level. The elevation at Indio is -20 feet, at Thermal, -126 feet, and at Mecca, -198 feet. The lowest point in the area before the inflow of the Colorado River in 1905 was about 280 feet below sea level.

The mountains support only a thin desertlike vegetation. The valley is treeless, excepting for such low growths as mesquite (*Prosopis sp.*), screw bean, and palo verde (*Parkinsonia microphylla*, Torr.). There are a number of desert shrubs, such as creosote bush (*Covillea sp.*), cat's-claw (*Acacia gregii*), arrowweed (*Pluchea sericea*), tassojia, cholla, ocotillo (*Fouquieria splendens*), and the alkali-resisting plants, saltbush (*Atriplex lentiformis*), pickleweed (*Allenrolfea sp.*), and samphire (*Salicornia sp.*).

The drainage of the entire valley is toward the Salton Sea. There are no perennial streams on the floor of the valley, the water flowing

<sup>2</sup> Soil Survey of the Indio area, California, Field Operations of the Bureau of Soils, 1903.

off the mountains following ordinary rains being absorbed by the porous sands and other deposits at the foot of the slopes without flowing over the surface of the agricultural lands. The surface water of the valley is derived almost entirely from the slopes of San Bernardino and San Jacinto Mountains. From these slopes small perennial streams flow into the desert. Of these the largest is the Whitewater River, which has its source on San Gorgonio Mountain, elevation 11,485 feet, the highest point in the San Bernardino Range. Ordinarily this stream flows over the surface for only a few miles before it sinks into the sands and thereafter finds its way through the porous materials to the Salton Sea. During years of disuse its channel through the valley becomes choked with sand, and following exceptionally hard rains on the snow-clad peaks it has been known to overflow its channel and flow unrestricted the entire length of the valley. Within recent years such floods have caused more or less damage by eroding the silty soils south of Indio and by flooding the town of Coachella. Since then a channel bordered by levees has been constructed for the purpose of conducting flood waters through the lower part of the valley to the Salton Sea.

The outer margins of the valley have good surface and internal drainage, but the greater part of the floor of the valley is poorly drained. In an area covering several square miles on the shore of Salton Sea and extending northward as a narrow strip along the trough of the valley to a point about 5 miles northwest of Indio, the water table is high, and there is a strong concentration of alkali on the surface.

Prior to the building of the Southern Pacific Railroad through the valley in 1879, the area surveyed was an uninhabited desert. As a bonus for building this line the Government gave the railroad company every alternate section of public land for a number of miles on each side of its right of way. Thus one-half of the valley was owned by the railroad. At the present time the greater part of the original holdings are still owned by the railroad company, which has sold only a few sections near the right of way. A large proportion of the remaining public land was filed upon in 1885 and 1886 under the desert-land act. There were very few settlers, however, until 1900, when it was discovered that it was possible to obtain artesian water for irrigation at comparatively small expense. Since that date there has been a rather slow but continuous growth of population.

The original settlers were mostly Americans from other parts of California, although now probably nearly every State in the Union is represented in the valley, the greater number being from the South Atlantic States. There are considerable numbers of Mexicans and Indians, the latter living on several reservations in different parts of the valley.

According to the United States census, the population in 1920 of Indio Township was 1,187; of Coachella Township, 1,016; of Thermal Township, 888; and of Mecca Township, 583; or a total of 3,674. Since these townships comprise practically all of the settled parts of the area surveyed, the total probably closely represents the population of the area. Indio and Coachella are the principal towns, with populations of 600 to 700 each, while Thermal and Mecca, also on the railroad, are slightly smaller. Indian Wells on the west side of the area, and Oasis on the Los Angeles-Brawley Highway in the

southwestern part, are small settlements. Martinez is the Indian agency and school for the Toro Indian Reservation. All of the population is classed as rural. Settlement is confined principally to the vicinity of the towns and a few outlying districts on the west side of the valley. A large proportion of the area surveyed is still uninhabited.

The status of lands in the area is shown by the following table covering the 72,000 acres reported as the irrigable area under the proposed All-American Canal:<sup>3</sup>

*Status of lands in the Coachella Valley*

[Acres]

Private	Entered	Public	Indian	California	Southern Pacific Railroad	Total
12, 100	3, 400	3, 800	11, 400	4, 400	36, 900	72, 000

The main line of the Southern Pacific Railroad traverses the length of the valley and gives direct communication with Los Angeles and San Francisco and the markets of the East. The area is well supplied with roads. The Los Angeles-Brawley Highway between Imperial Valley points and Los Angeles extends the length of the Coachella Valley. Another paved highway joins Coachella, Thermal, and Mecca and extends northwest of Indio nearly to Palm Springs. One extends west of Thermal to beyond the Union High School, one a short distance north of Indio, and one north of Point Happy along the base of the mountains for several miles. The unpaved roads are fairly good in the lower part of the area, but the few roads on the outer margins of the valley are very sandy and in poor condition. Telephones are in general use throughout the area and several schools are located at convenient intervals.

Los Angeles and San Francisco are important markets for winter vegetables and grapefruit. Dates are disposed of in small orders in all parts of the United States. Onions are shipped to the principal cities in the East. Part of the cotton is disposed of in Los Angeles, but the greater part is taken by eastern buyers. The cotton seed, which is of high quality, is sold locally or shipped to near-by cotton-growing sections for planting. The towns in the valley constitute small but important markets for vegetables, dates, and citrus fruits.

#### CLIMATE

The climate of the Coachella Valley is decidedly arid. It is characterized by long, extremely hot summers, with occasional high temperatures throughout the entire year, mild winters, a low relative humidity, cloudless skies, and an almost negligible rainfall. Frosts are rare, and snow, hail, fog, thunder, lightning, and destructive winds are practically unknown in the valley. However, snow is common on the near-by mountains in winter, and some of the higher peaks remain snow clad until midsummer. The mean annual temperature at Indio, according to the records of the United States Weather Bureau, is 73.4° F.

<sup>3</sup> Senate Document No. 142, Problems of Imperial Valley and Vicinity, 1922.



The following tables, compiled from records of the United States Weather Bureau, give the normal monthly, seasonal, and annual temperature and precipitation at Indio and Mecca during the periods for which records have been kept:

*Normal monthly, seasonal, and annual temperature and precipitation at Indio*

[Elevation -20 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1894)	Total amount for the wettest year (1906)
	° F.	° F.	° F.	Inches	Inches	Inches
December.....	55.5	90	17	0.39	0.00	1.89
January.....	53.4	90	16	.82	.00	T.
February.....	53.7	92	24	.44	.00	.97
Winter.....	55.9	92	16	1.65	.00	2.86
March.....	65.0	104	27	.32	.00	2.06
April.....	72.4	110	36	.07	.00	.47
May.....	79.0	121	33	.02	.00	.00
Spring.....	72.1	121	27	.41	.00	2.53
June.....	88.0	120	55	.01	.00	.00
July.....	93.6	125	62	.04	T.	T.
August.....	92.4	120	48	.16	.00	1.07
Summer.....	91.3	125	48	.21	T.	1.07
September.....	85.9	118	48	.22	.00	.04
October.....	76.2	110	36	.14	.00	T.
November.....	62.8	98	23	.20	.00	.60
Fall.....	74.6	118	23	.56	.00	.64
Year.....	73.4	125	16	2.83	T.	7.10

*Normal monthly, seasonal, and annual temperature and precipitation at Mecca*

[Elevation -185 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1924)	Total amount for the wettest year (1926)
	° F.	° F.	° F.	Inches	Inches	Inches
December.....	52.9	87	17	0.31	0.07	1.72
January.....	52.2	81	13	.79	.00	.00
February.....	56.8	89	25	.37	.00	1.04
Winter.....	54.0	89	13	1.47	.07	2.76
March.....	62.8	102	28	.43	.05	1.37
April.....	70.2	104	38	.10	.24	.63
May.....	77.2	116	38	.01	.00	.00
Spring.....	70.1	116	28	.54	.29	2.00
June.....	84.7	124	51	.00	.00	.00
July.....	90.1	116	60	.11	.00	.10
August.....	89.2	118	59	.46	.00	2.60
Summer.....	88.0	124	51	.57	.00	2.70
September.....	83.7	112	52	.09	.05	.00
October.....	72.4	111	38	.22	.00	.00
November.....	61.5	96	21	.28	.00	.60
Fall.....	72.5	112	21	.59	.05	.50
Year.....	71.1	124	13	3.17	.41	7.96

It will be seen that the highest recorded temperature at Indio is 125° F., and that 118° or more has been recorded during every month from May to September, inclusive. The maximum temperature for April and October is 110° and for March 104°. Every month in the year the temperature has risen to at least 90°. The lowest recorded temperature at Indio is 16°; at Mecca, 13°. Killing frosts are likely to occur from about the 1st of December until the middle of March. They have occurred at Indio as early as November 12 and as late in the spring as March 16, but the average date of the last in the spring is February 10. Frosts are not a serious handicap to agriculture in the Coachella Valley, as onions and a great variety of vegetables are grown during the winter months. However, the winter nights are prevailingly cool, and plants do not make rapid growth during this period. Although the summers are exceedingly hot, the low relative humidity renders the heat no more oppressive than lower temperatures in other sections where the humidity is higher. The winters are exceptionally agreeable.

There is very little rainfall, the average annual precipitation at Indio being 2.83 inches. At Mecca the average is 3.17 inches, the difference apparently being due in part to the shorter period during which records have been kept at Mecca. The rainfall is not only insignificant, but its distribution is such as to make it undependable for agriculture. As a rule the greater part of it comes during the winter in rather hard rainstorms of short duration. Periods of more than 12 months have elapsed with no rain falling in measurable quantities, and frequently three to six months elapse without a trace of rain. The precipitation increases toward the west end of the valley, being 4.35 inches at Palm Springs, elevation 584 feet, and 19.19 inches at Beaumont on the crest of the San Gorgonio Pass. There is a high rainfall on the mountains to the west, the annual precipitation at Nellie, elevation 5,350 feet, being 50.31 inches. This high precipitation falling on the slopes of San Jacinto and Santa Rosa Mountains supplies the underground waters for the irrigation in this valley. Except after heavy storms in the mountains, these waters enter the sands near the edge of the valley and thus are saved from evaporation that would otherwise occur if they continued to flow over the surface.

Owing to the high temperature and almost daily sunshine, evaporation is very high during every month of the year. From studies made it is estimated that the evaporation from the surface of the Salton Sea is 6.73 feet per annum.<sup>4</sup> The spring months are characterized by strong northwesterly winds which blow toward the desert from the San Gorgonio Pass and the mountains on each side of it. These winds, sweeping over the surface, have formed many square miles of sand dunes in the upper part of the valley, and each year the sands are carried farther eastward and southward onto the floor of the valley. The winds usually blow for two or three days in succession, during which time the atmosphere is heavily charged with dust. Dust storms are more common in the northern and western parts of the area surveyed than in the southern part, the section

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<sup>4</sup> Water Supply Paper 395, Colorado River and Its Utilization, United States Geological Survey.

between Mecca and the Salton Sea being comparatively free from them.

In general, the climate of the Coachella Valley is very favorable for the growing, under irrigation, of such specialized crops as dates, grapes, citrus fruits, and winter vegetables. Many of these products come on the market at a time when there is little competition from other sections.

#### AGRICULTURE

The Southern Pacific Railroad completed its line through the valley in 1879. For this service it was given every alternate section for a distance of several miles on each side of the line. During 1885 and 1886 most of the remaining public lands were filed upon under the desert land act. No agriculture was practiced, however, until several years later, as there was no water available for irrigation. In 1894 the first strong flow of artesian water was obtained, thus proving definitely its existence in the valley. Still no agriculture was developed, as the cost of drilling deep wells by the method then in use was prohibitive. In 1900 the hydraulic method of drilling wells was introduced into the valley, which so lessened the cost that within the next three years about 200 artesian wells were bored for irrigating purposes. From that time agricultural development has been continuous. The first crops grown were melons, barley, and alfalfa, with smaller acreages of corn, kafir, and sweet potatoes. Melons and sweet potatoes were cash crops; the others were used locally as feed for stock. According to Mendenhall,<sup>5</sup> "about 60 acres of cantaloupes were planted in 1901, netting the growers \$10,000. In 1904 the Melon Association of Coachella distributed \$67,000 to its members, and in addition the independent operators shipped 11 cars from Indio." By 1909, according to the same authority, there were 350 to 400 deep wells in the valley, of which 300 were artesian. At this date about 50 pumping plants had been installed at a total estimated cost for development and distribution of \$200,000. The total area under irrigation at this time is estimated to have been between 4,000 and 5,000 acres.

In 1904 a Government agricultural experiment station was established at Mecca for the purpose of studying the adaptation of the section to date culture. A number of varieties were imported from Egypt, Algeria, and the countries around the Persian Gulf. Since then a number of importations have been made both by the United States Department of Agriculture and by private individuals.

A considerable acreage of grapes was planted in 1906 and 1907. The acreage increased until about 1910, when it was about 200 acres. This early venture proved unprofitable, so in 1911 and the years following many of the vines were removed, but five or six years later the industry was revived.

Cotton was introduced about 1910, but after a trial of one or two years it was found that the low price then prevailing was not enough to justify the high expense in growing the crop where water had to be pumped with gasoline engines for irrigation. With the higher

<sup>5</sup> Walter C. Mendenhall, Water Supply Paper 225, Ground Waters of the Indio Region, California, U. S. Geological Survey.

price in 1915 this industry was revived and a considerable acreage of the Pima variety was planted.

The following table, furnished by the Bureau of Agricultural Economics, United States Department of Agriculture, shows the number of cars of products shipped from the various points in the valley during 1919, 1920, 1921, and 1922:

*Commodities shipped from the Coachella Valley*

[Carloads]

Shipping point	Cantaloupes	Grapefruit	Grapes	Lettuce	Onions	Spinach	Sweet potatoes	Watermelons	Mixed vegetables
Coachella:									
1919	4		39	6	(1) 694	4		16	
1920			33	8	365	88			
1921			35	18	592				
1922		2	31	5		23			1
Indio:									
1920					225			6	
1921					118				
1922					182				
Mecca:									
1919		1	20				1		
1920		1	20		8				
1921			2						
1922			3						
Thermal:									
1919			11		(1) 508	10			
1920			24		314			6	
1921			36		331				
1922		10	44				2		

<sup>1</sup> 1919 records only from July to December. However, all figures for that year are correct except for onions, which are shipped before July.

In addition to these crops cotton and a number of other products were shipped for which figures are not available. Not only do the crops grown vary from year to year but the acreage frequently shifts from one part of the valley to another. For example, in 1919 Coachella was the only point in the valley from which cantaloupes, watermelons, and spinach were shipped. In 1920 large shipments of spinach were made from Coachella and Thermal; in 1921 none; and in 1922 only Coachella made shipments of this crop. Mecca made the only shipment of sweet potatoes in 1919, Thermal the only one in 1922. Indio made the only shipment of watermelons in 1920, Thermal the only one in 1921. In like manner the acreages of other special crops shift from point to point. All of these products, including cotton and fruits, are grown as cash crops. Onions are the most important. In 1920 the total shipments of onions reported for the valley amounted to 1,435 cars; in 1921, 787 cars; and in 1922, 1,105 cars. Although during the last two years there has been a considerable increase in the acreage of grapes, the volume of shipments during the last four years has been almost constant. In 1919, 70 cars were reported for the area; in 1920, 77 cars; in 1921, 73 cars; and in 1922, 78 cars.

The following table, compiled from information furnished by the county horticultural commissioner, gives the acreages of the principal crops in 1920 and 1922:

*Acreeages of various crops in the Coachella Valley in 1920 and 1922*

Crop	1920	1922	Crop	1920	1922
	<i>Acres</i>	<i>Acres</i>		<i>Acres</i>	<i>Acres</i>
Onions.....	3,000	2,700	Tomatoes.....	110	87
Grapes.....	553	1,274	Sweet potatoes.....		20
Cotton.....	2,000	1,250	Figs.....	14	19
Dates.....	299	618	Asparagus.....	12	
Alfalfa.....	125	160			
Grapefruit.....	32	122	Total.....	6,145	6,250

The agriculture of the valley is still very new. From the beginning there have been frequent changes in the crops grown, as special marketing or growing conditions seemed to make it advisable to increase or diminish the acreages. A study of the above tables indicates that the cropping system still shows the same lack of uniformity as characterized it in the past. This condition would be still more strikingly shown if the figures for 1923 were considered. In 1920, onions occupied 3,000 acres; in 1921, a little more than one-half that acreage; in 1922, 2,700 acres; and in 1923 the acreage is reported to have fallen off to less than 1,500 acres. Cotton in 1920 occupied 2,000 acres; in 1922 only 1,250 acres; and during the present season of 1923 this crop is said to occupy about 4,500 acres. The acreages of all other annual crops show the same degree of variability.

Notwithstanding the fact that the production of all annual crops is so variable, it is apparent that a permanent system of agriculture is being established through the steady increase in the acreage of such permanent crops as dates, grapes, and grapefruit. The acreage of dates in 1922 was 618 acres—more than double the acreage in 1920. Grapes increased from 553 acres in 1920 to 1,274 acres in 1922. The increase in grapefruit was about fourfold, or from 32 acres in 1920 to 122 acres in 1922. It is estimated that the increases for this year (1923) have been fully as great as for 1922.

At the present time the agriculture of the Coachella Valley consists of the growing of cotton, winter truck crops and fruits for sale; the raising of alfalfa, milo, and grain hay for feeding work stock; the raising of poultry and poultry products for sale and for home use; dairying for the local markets; and the raising for home use of nearly all of the food commodities required on the farm.

The truck crops consist principally of onions, with smaller acreages of peas, beans, peppers, tomatoes, cantaloupes, watermelons, sweet corn, eggplant, and squash. The fruits consist principally of grapes, dates, grapefruit, and figs, with smaller acreages of oranges, lemons, and some almonds, pomegranates, and olives, the last two grown mostly as border trees around other fruits.

Cotton during the season of 1923 occupied the largest acreage, the estimate for the valley being 4,500 acres. During the last few years a special effort has been made to produce the Acala variety only, thus assuring conditions under which a pure strain of seed of superior quality can be produced. The Acala is a new and very desirable variety which is being developed in the Coachella Valley on a commercial scale under the supervision of a representative of the United States Department of Agriculture. Although the average yield for the valley is a little less than 1 bale per acre, the yield

has been increased to nearly 2 bales per acre on well-cared-for fields. (Pl. 16, fig. 1.) The lint is sold independently, but the seed is distributed through a growers' association. During the last two years enough seed has been produced to permit shipping considerable quantities to other cotton-producing districts, where it has commanded a premium over the price of other varieties. In a number of instances the returns from the sale of the seed have been enough to pay the entire cost of producing the crop. The restriction of the acreage to one variety has placed the cotton-growing industry in an advantageous position, as it makes possible the production of pure seed on a commercial scale. The crop is free from pests, which gives the valley an additional advantage over the cotton-growing sections in the East.

Cotton is confined principally to the medium and heavy textured soils of the Indio series. In preparing the land, the soil is plowed dry early in the spring and thrown up into ridges about 4 feet apart. Following this, the land is irrigated and sometimes harrowed, after which the seed is drilled along the tops of the ridges. Picking begins in September and continues well into January. Owing to the mildness of the winters it is sometimes possible to obtain very good stands by volunteering. Cotton is a rather expensive crop to grow under the conditions prevailing in the Coachella Valley. The future of the industry is dependent on a profitable price for lint and the degree of cooperation among the growers in the production of pure seed which will command a premium over that produced in other sections.

In point of acreage, onions constitute the second crop of importance in the area, although the acreage fluctuates from year to year, depending on the price. At the present time (1923) the acreage is being reduced and many of the growers have about decided to abandon this crop in favor of others in which the risk of loss is not so great. Although the yields obtained in the Coachella Valley rank favorably with those of other sections, the crop is slow in maturing owing to the absence of warm nights in winter. Large shipments from southern Texas begin moving to market two to three weeks before the Coachella Valley crop is ripe enough to harvest, and the result is a market already more or less stocked. Efforts to advance the date of maturing the crop have not been satisfactory. On the other hand, retarding the date of ripening entails additional risk from sun scald, as hot weather usually prevails during the latter part of May. Apparently little is to be gained by attempting to market the crop before May 1.

The principal varieties are the Yellow Bermuda and the Crystal Wax, the former occupying about 80 per cent of the acreage. The Crystal Wax usually commands a good price, but it yields somewhat less and does not stand up well under adverse shipping conditions. Formerly considerable quantities of seed were produced in the valley, but at present most of the seed is obtained from the Canary Islands.

The seed is usually planted in beds in September and transplanted to the fields in November and December, about 100,000 being planted to the acre. In preparing the land the fields are thoroughly cultivated and then thrown up into ridges about 2 feet apart. Usually



S. 14500

FIG. 1.—ACALA COTTON GROWING ON INDIO LOAM



S. 14505

FIG. 2.—ONIONS RECENTLY TRANSPLANTED ON INDIO VERY FINE SANDY LOAM, SHOWING METHOD OF PREPARING LAND FOR PLANTING AND IRRIGATION





two rows,  $3\frac{1}{2}$  to 5 inches apart, are planted on the tops of the ridges, the plants being about 4 inches apart in the rows. Some growers use only the single-row system. The young plants are set out in dry soil, usually by Mexican hand labor, and the fields are watered immediately thereafter. (Pl. 16, fig. 2.) The crop is cultivated frequently during the winter and irrigated at intervals of three or four weeks, depending on the soil, until some time in March, after which water is applied more frequently. In harvesting, a horse-drawn sled with knives attached is run down the rows to loosen the roots from the soil and permit the onions to be easily pulled by hand. After a short period of curing, the onions are topped, graded, and packed, usually in the field, and delivered as soon as possible to the railroad for shipment. During the last three seasons the grading has been done according to United States standards and under the direct supervision of a force of trained men who inspected each load as it was delivered to the cars.

The cost of growing onions varies greatly, according to the yield, the expense of pumping water, and the price of labor. The total cost of producing onions, including harvesting, crating, and delivering to the station, is approximately 90 cents a crate.<sup>6</sup> This is on the basis of an average yield of 250 to 300 crates per acre. When the yield is less the cost is proportionately higher. The average yield for the valley is reported to be around 250 crates per acre.

Grapes are now (1923) the third crop in importance in the valley, although at the present rate of planting they may soon occupy the largest acreage. The grapes grown consist entirely of table varieties and are the first to reach the market. Shipping usually begins about the last week in June and continues until the latter part of July. Prominent growers estimate that between 90 and 95 per cent of the grapes grown are of the Malaga variety and the rest Sultanina (Thompson Seedless). The latter variety is the first to ripen, but the fruit shatters badly and is not so good a shipper as the Malaga. Yields range from 150 to as much as 500 crates per acre, the average for the valley probably being between 200 and 250 crates per acre. Although these yields are somewhat less than those obtained in some of the other grape-growing districts, the early ripening period brings them on the market at a time when there is little competition and the price received is usually highly remunerative.

Grapes are grown on a variety of soils ranging from light-textured sands to loam and silt loam. The fruit ripens earliest on the light-textured soils; it is said to average somewhat better in quality and to suffer less damage in shipping. The yields, however, are slightly lower than those produced on the heavier soils. The most successful growers give considerable attention to cultivation. Rye or barley is frequently grown both as a cover crop and as a nurse crop to protect the vines from being injured by blowing sand. Bean straw and other refuse is plowed under whenever available. During the present season commercial fertilizers are being used at the rate of 2 to 4 pounds per vine, depending on the age of the vine. About two-thirds of the total quantity is applied just before the first irrigation in the spring, and the rest about the time the fruit is beginning

<sup>6</sup> Special Publication No. 31, Calif. Dept. of Agr., Growing, Harvesting, and Marketing California Bermuda Onions, by H. H. Warner.

to set. Soon after pruning the vines in late winter or spring the vineyards are irrigated, and thereafter water is applied about once a month until the ripening period. The vines are watered following the harvest, and sometimes again in the fall. The leaf hopper, the only serious pest as yet encountered in the industry, is effectively combated by the application of nicotine sulphate in dust form.

Dates, from the standpoint of financial returns, are fast becoming the most important crop in the Coachella Valley. The date industry began in the valley in 1904, when experimental plantings were made of palms imported from North Africa and the countries around the Persian Gulf. Following this, importations continued both by the United States Department of Agriculture and by private individuals until 1915, when the industry was checked by the decree of the French Government prohibiting export of palms except for experimental purposes. The industry is still very new, but much valuable information has been gained concerning methods of culture and concerning the adaptability of many varieties. As a result of these tests only 8 or 10 varieties are recommended for general commercial planting in the Coachella Valley. The Deglet Noor heads the list of the approved African varieties. The uniformly dry air which prevails in this valley during August and September seems to be particularly well suited to this variety, which is said to be especially sensitive to atmospheric conditions that produce a dew point during the period of ripening. Other varieties from North Africa include the Saidy, Thoory, Tazizaoot, Iteema, and Hayany. Among the promising Persian varieties are the Khadrawy, Halawy, and Maktoom. The Khadrawy is a soft, sugary, early-ripening variety occupying a considerable acreage in the vicinity of Thermal.

The palms begin bearing at 4 or 5 years of age, and when 8 years old should be returning good yields. From this age on commercial plantings of desirable varieties have yielded 80 to 150 pounds per palm, or an average of about 5,000 pounds per acre. (Pl. 17.) Soon after picking, the fruit is processed, carefully graded, and packed, most of it in sealed containers containing 1 to 2 pounds each, and a large proportion of it is marketed through cooperative date growers' associations. A number of growers still pack and sell their fruit independently, and considerable quantities are sold locally in bulk. The local price for good fruit in bulk ranges from 35 to 50 cents a pound, whereas choice dates packed in 1 to 2 pound boxes sell for 75 cents to \$1.25 a pound. The total yield of dates for 1922 is reported to have been about 260,000 pounds, and the production for 1923 is estimated at about 400,000 pounds.

In addition to the fruit, there is a considerable revenue from offshoots. The first offshoot may be removed about the third year. Thereafter, during the next 8 or 10 years (after which offshoot-production ceases) the average palm produces about 10 offshoots (the number differing with varieties), which, in the case of the Deglet Noor, sell for \$10 to \$20 each. Thus it will be seen that at the present price of offshoots the cost of planting dates is exceedingly high. However, the cost is not out of proportion when one considers the exceptionally large returns that are being obtained from well-cared-for groves.



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FIG. 1.—VIEW IN A BEARING DATE ORCHARD



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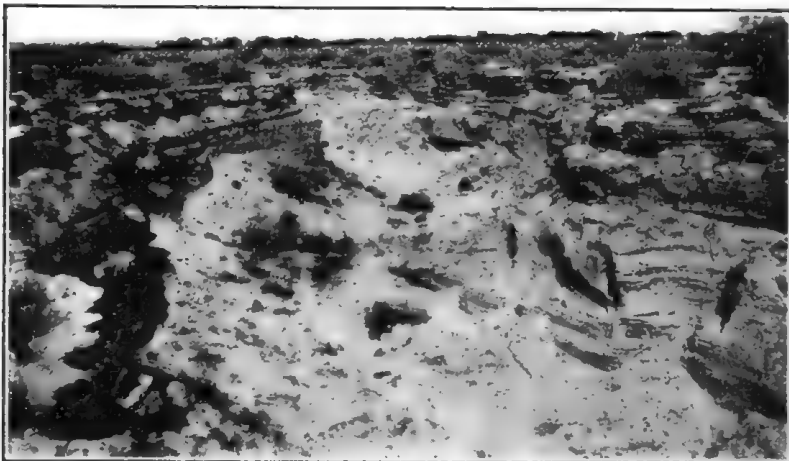
FIG. 2.—BEARING DATE PALM

Showing method of protecting clusters of fruit with paper bags or wrappings



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**FIG. 1.—DATE PALM, WITH OFFSHOOTS AT BASE, FROM WHICH NEW PLANTINGS ARE PROPAGATED**



S. 14508

**FIG. 2.—STRATIFIED MATERIALS OF THE INDIO SOILS EXPOSED IN A DRY, DESERT STREAM WASH**

In the beginning of the date-growing industry there were many disappointments, owing to inexperience, but during the last few years much progress has been made in the manner of rooting offshoots. A number of the first plantings in the valley are grown from seed, but as seedlings rarely come true to variety and produce a large percentage of male plants, most of the seedling groves are of low value. Since the offshoots produced by the female trees are true to type, it is advisable to use only offshoots in starting a commercial grove. (Pl. 18, fig. 1.) Until recently offshoots were removed from the palm when young and rooted in houses; this method was not only expensive but resulted in a large percentage of loss. At the present time two methods are in general use. One is to remove the shoots when young and transplant them in a nursery in the open field. The other and more common method is to root the offshoots on the parent tree; in doing this the palm is originally set in a basin a foot or more below the level of the ground, and as the shoots appear at the base the soil is drawn in around the trunk. Sometimes instead of removing the offshoots separately one shoot is detached and left in place, while the parent palm, with the remaining shoots attached, is removed to a new location. Thus by transplanting the more vigorous plant, with its stored-up energy, it can be made to grow on lands having a surface concentration of alkali that would preclude the starting of a smaller plant. When established in its new location, the remaining shoots are removed and transplanted elsewhere.

The date palm requires much water. Old groves are irrigated at least twice a month and young palms three times a month or oftener. Well-cared-for groves are irrigated every month in the year. On light-textured soils rye or barley is sometimes grown as a cover crop and plowed under in March, but the majority of the groves are given clean cultivation the year around. Commercial fertilizers are beginning to be applied, but their use on dates is still in the experimental stage.

Of all plants commercially grown in the valley the date palm, when once established, is probably least affected by alkali. From studies made by the United States Department of Agriculture it has been found that the palm will thrive in soils having a surface concentration that would preclude the growth of any of the common crops, provided the roots have access to a layer in the soil containing not more than 1 per cent of salts. However, as long as better lands can be obtained in the Coachella Valley at the present prices, it would seem unwise to plant inferior lands to a crop having such a high cost of production and high potential value. It is estimated by authorities of the University of California Agricultural Experiment Station that the cost of bringing a date orchard into bearing will average about \$3,000 an acre. Actual sales of date groves 5 to 6 years old are reported at \$3,000 to \$4,000 an acre; however, there are said to have been a number of refusals of \$6,000 an acre.

Alfalfa is a crop of some importance, although the total acreage in 1922 was only 160 acres. It is grown for feeding work animals on the farms, and the total quantity produced is far short of what is consumed in the valley. From 5 to 10 tons per acre per season are

obtained. The low acreage is due to the high cost of growing the crop under the prevailing conditions.

Grapefruit is a crop of increasing importance, the acreage having increased from 32 acres in 1920 to 122 acres in 1922. During the present season (1923) a considerable additional acreage has been planted. The fruit is of superior quality and commands a high price in the market. Shipments begin before the winter holidays, which is somewhat earlier than the ripening period in other parts of the State. Grapefruit plantings are confined principally to the light-textured soils, although there are some recent plantings on loam and clay loam types. The trees come into bearing about the fourth year. They are grown mostly under clean cultivation, although rye or barley is sometimes planted in young groves in the fall and plowed under the latter part of winter. In the past there has been little fertilizing, but during the present season quantities of farmyard manure have been hauled by truck from the Imperial Valley and applied to the groves.

Oranges are grown in a small way and are said to be of good quality. Figs occupied 19 acres in 1922. This fruit bears heavily in the Coachella Valley, and because it ripens early it is disposed of as fresh fruit in Los Angeles. A few apricot, pomegranate, olive, and almond trees are grown, but as yet they have no commercial value.

Barley and wheat are grown in all parts of the area, and there is a small acreage of oats. The greater part of these crops is cut green for hay and used for feeding work animals. Small acreages of corn and milo are also grown for feed.

Tomatoes occupied 110 acres in 1920 and 87 acres in 1922. The plants are set out about the middle of November and protected by paper and brush shelters as long as there is danger of frost. Shipping begins the latter part of April or early in May. Tomatoes are grown principally on the sandy soils in the vicinity of Oasis, with a small acreage near Coachella.

Green peas and string beans are important cash crops in the vicinity of Indio. These crops are planted from September 1 to November and are marketed, principally in Los Angeles and San Francisco, from the middle of November until the latter part of March. Yields average about 2 tons per acre and the prices range from 8 to 15 cents per pound.

Other cash crops grown principally in the winter include peppers, summer squash, asparagus, spinach, and okra. These crops are confined principally to the light-textured soils in the vicinity of Oasis and Coachella. Peppers are grown both in the open and under cover. When grown under cover, the seed is sown from the middle to the end of October and later covered with muslin. The cover is not removed, except for hoeing, until the crop is harvested, which is usually about the first week in April. The returns from peppers are reported to be very high; but the expense is also high, the covers alone costing \$1,000 or more for an acre. Summer squash is planted from January 1 until early spring and marketed from April until July.

Watermelons are of local importance on the sandy soils near Indio. Cantaloupes, which were formerly extensively grown, have

been largely discontinued, partly because of the expense of growing the crop where water has to be pumped for irrigation and partly because of the damage caused by thrips.

The livestock industry is of very little importance in the valley. A few cows are kept to supply the homes with butter and milk, and small dairies supply milk to the local towns. The cows are pastured throughout the year, principally on alfalfa. A few hogs are kept. Most of the farmers keep a few chickens, and a few turkeys are raised for sale.

Excellent opportunities exist in the Coachella Valley for extending the acreage of dates, grapefruit, and grapes. The growing of dates has passed the first experimental stage, and the results obtained by a number of successful growers have demonstrated the market adaptability of this high-priced product to the soil and climatic conditions in the valley. The quality of Coachella Valley dates is so far superior to that of the imported product that there need be little fear of competition. The grapefruit produced not only commands a premium in price because of excellent quality but it is among the first to reach the market, which assures a ready sale for all that is likely to be grown in the valley. Table grapes in the Coachella Valley should continue to be profitable, since their early ripening period brings them on the market when there is practically no competition.

The soils of the area have had a pronounced influence in the distribution of crops, practically all of them being confined to the light or medium-textured types. The soils of the Woodrow series and the heavy types of the Indio series, being strong in alkali, are used but little for crops of any kind. The rough topography and loose character of dunesand and the wind-blown types of the Coachella series have retarded development in the section west of Indio and Coachella. The stony character and the high position of the most of the Superstition soils above the level at which water can be economically developed for irrigation restricts the agriculture of the valley to the lower-lying areas.

The farmers recognize that the Indio very fine sandy loam and loam are the best soils for onions, and that well-drained light to medium textured soils are essential to success in growing grapes, particularly of the Malaga variety. They recognize that dates, when once established, will grow in soils containing a high content of alkali but that they make a more thrifty growth in alkali-free soils which are of medium to light texture without dense strata in the subsoil. The medium to light textured soils, such as the Indio very fine sandy loam and very fine sand, are considered best for vegetables, the coarser sands being considered too porous for these crops. The fine sandy soils are also held in high esteem for grapefruit, oranges, and watermelons.

All of the crops grown in the Coachella Valley, except the small quantities grown for feed, are cash products and are marketed immediately after harvesting. The agriculture is highly specialized and calls for considerable skill and large expenditures in operation. The crops are mainly high-priced products, since the climate is such that they may be made to reach the markets at a time when there is little competition. As the acreage of the highly specialized crops,

such as dates, grapes, and grapefruit, is increased, the area devoted to the more common crops is diminishing, and the fact that during the last two years the acreage of these permanent crops has increased two to three fold shows that the trend is toward a permanent type of agriculture in the valley.

Owing to the mild climate, the farm buildings throughout the valley are inexpensive. There are no barns for storage, and the few stables provided for livestock are temporary sheds. The work animals consist of light to medium-weight horses and mules, the small size of the fields and the character of the crops being such that very little farm work can be done with tractors. The implements used are mostly of light weight. Most of the hauling, however, is done with medium to heavy trucks.

In growing onions most of the cultivation is done with hand cultivators, although some growers arrange the rows in such manner as to permit the use of burros. In vineyards a thoroughly pulverized mulch is maintained on the surface to prevent the formation of a crust. Dates are irrigated and cultivated every month in the year; grapes only from the latter part of winter until after harvest in July.

No definite rotation of crops is practiced in the valley, the crops selected for planting in the past being governed by price conditions rather than the effects which they might have upon the soils. In some cases cotton has followed cotton, and onions have occupied some fields several years in succession. Frequently winter truck crops are followed by spring vegetables, and truck crops are often planted in the fall on fields from which onions were harvested the spring before. In a few instances onions have been grown in vineyards and date groves two or more years in succession. Most of the fruit crops, however, are given clean cultivation the year round. Alfalfa usually occupies the land for several years.

Until the last year practically no commercial fertilizers were used in the Coachella Valley. During the present year (1923) small quantities have been shipped in for use on grapes, onions, and vegetables. Increasing quantities of barnyard manure are hauled by automobile trucks from the Imperial Valley and used on vineyards and citrus groves. Some of the better farmers sow *Melilotus indica* in date groves in the fall to be plowed under the latter part of winter. All available supplies of bean straw and other organic refuse are carefully conserved and applied to vineyards and date groves. The commercial fertilizers being used consist principally of nitrogen, phosphorus, and potash, although some are experimenting with gypsum in the belief that the soils are lacking in available lime.

The supply of farm labor is fairly abundant. Most of the hired help is Mexican; it is fairly efficient and somewhat cheaper than American labor. The average wage is \$2.50 a day without board. The work of transplanting onions is usually done under contract, \$20 an acre being paid in 1922 and \$25 in 1921. The price for topping onions ranges from 10 to 15 cents per crate. Cotton picking is usually paid for by the pound.

No definite figures are available regarding the size of farms in the Coachella Valley. The better improved ones will probably range between 20 and 40 acres in size, although there are many vineyards and date groves containing only 5 to 20 acres. There are a few



farms containing as much as 160 acres, but the most of the holdings of this size are unimproved. The Southern Pacific Land Co. still holds practically all the land granted to it. Only about 5 per cent of the area surveyed, and a much smaller percentage of the entire valley, is under cultivation. A rather large proportion of the farms in the valley are owned by nonresidents, who lease them, usually on the share basis, the owner furnishing work animals and implements and receiving one-fourth of the crop. A number of the highly developed groves are operated by managers.

Irrigated lands in the Coachella Valley adapted to general farming sell at present (1923) for \$200 to \$400 an acre. Vineyards are held at \$1,000 or more an acre, and grapefruit orchards at \$1,500 to \$2,000 an acre. Date groves have sold for \$4,000 an acre. A number of the better date groves are held at higher figures. Good unimproved land suitable for irrigation, well located, and adapted to grapes, grapefruit, and dates can be had for \$100 to \$150 an acre. Some of the rougher wind-blown soils and large areas containing alkali are on the market at \$15 to \$20 an acre.

#### SOILS

The Coachella Valley area is situated in the southwestern arid soil region and is a part of the generally treeless, desert valley extending from San Geronio Pass on the northwest to the Gulf of California in Mexico on the southeast. This important physiographic province, some 200 miles in length, is bordered on the west by ranges of the Coast Range system of mountains and on the east by a succession of lower arid ranges and desert plains. Its lower part lies 100 to 250 feet below sea level. Into this basin, formerly occupied by a large body of water, the Colorado River carried in suspension immense quantities of fine sediments which were deposited until the basin had been filled to a depth of several hundred feet. In addition, for long periods the entire valley has served as a catchment basin for alluvial sediments washed down from the mountains.

These deposits have accumulated under peculiar climatic conditions. Although less than 100 miles from the ocean, the region is shut off by the mountains from the moist ocean winds and in consequence has extremely high temperatures and a very scanty and undependable rainfall. The average precipitation is less than 3 inches a year and is so unevenly distributed that frequently periods of many months elapse with no rain falling in measurable quantities. The soil-forming materials have been subjected daily for months at a time to temperatures around or above 100° F. Only rarely is there sufficient rain to wet them more than a few inches in depth, and following the infrequent wettings they are quickly dried by evaporation and again subjected to the influence of the desert sun. So dry are the soils at practically all times that they are useless for agriculture without irrigation. Such conditions have a marked influence on the processes of soil accumulation and development.

The vegetation throughout most of the valley, consisting of small scattering shrubs, is also typical of deserts. The rainfall has been insufficient to produce grasses or trees, with their beneficial contribution of organic matter, and the soils are strikingly lacking in humus. In this respect the soils and subsoils are similar.

Having been subjected to identical climatic conditions, and being derived mainly from similar materials, the soils of the area have a number of important attributes in common. All are deficient in organic matter; all are highly micaceous and rich in soluble mineral materials, including lime carbonate; all show definite surface horizons of structural development wherever there is a surface concentration of salts; and all are light colored throughout the entire profile. In addition they are all irregularly stratified with no uniformity in thickness, texture, or order of arrangement of strata (pl. 18, fig. 2), and all have been derived from unconsolidated materials transported and redistributed by water or winds.

The source of the soil-forming material in the Coachella Valley area is principally in the near-by mountains. On the west the mountains consist mainly of hard, gray, massive granite, with some metamorphic igneous rocks. The rocks are highly micaceous, a characteristic which has been imparted to practically all the soils of the area. On the north and east the parent materials are of mixed mineralogical character. In addition to the same kinds of rock as on the west side, there are old water-laid deposits locally known as "mud hills." In places these deposits consist of clays and other fine materials, but most of them are of coarse texture and contain granitic gravel and angular rock fragments. They vary in the degree of consolidation from fairly loose materials to soft sandstones and conglomerates. As soil-forming materials they differ somewhat from the rocks on the west side of the valley; and although they have influenced the soils along the east side by producing small areas in which there is greater compaction in the soil profile, their influence in determining soil characteristics has been overshadowed by the dominating climatic conditions under which the soils of the entire valley have accumulated.

The soils of the valley are all young; and although weathering of the accumulated soil materials has taken place to an immature degree, very little progress has been made in development of weathered, structural soil horizons. The differences that occur throughout the soil profile are usually differences of deposition rather than of soil development. They are mainly geological horizons, although under certain conditions definite structural soil horizons occur in the lower-lying soils of the valley. These horizons are apparently due to the presence of soluble mineral salts which, accumulating at the surface, have formed thin crusts and subsurface mulches, or in places seem only to have contributed to the formation of a slightly compact horizon in tilled fields just below the depth of cultivation. These are developed alike in all the soils on the valley floor, regardless of their age, origin, or method of deposition.

The presence of a high percentage of soluble mineral salts is a common characteristic of desert soils. Frequently they become so abundant as to constitute injurious accumulations of alkali, which are a menace to agriculture. Since irrigation is confined principally to desert soils, the materials for forming alkali are usually more or less abundant in irrigated areas; and although at first alkali may be absent or only of local occurrence, it is in general a possibility which should be reckoned with.

Based on age or the degree of weathering, and the manner of accumulation and subsequent distribution of the soil materials, the soils of the area are grouped or classified into old valley-filling soils, recent alluvial soils, lake-laid soils, and wind-blown soils. In addition, rough broken and stony land, a nonagricultural type occupying the foothills and mountains, is mapped.

The old valley-filling group of soils occupies old alluvial fans and slopes lying between the valley floor and the mountains. Typically the soils of this group are distinguished from the soils of more recent deposition by certain marks of weathering, such as the development of definite horizons of clay accumulation or compaction in the profile, but owing to low rainfall, migration of the finer soil particles to the subsoils has taken place in this region only to a slight extent, and the subsoils are frequently coarser textured than the surface soils. The materials are unleached of soluble minerals; apparently they have an abundance of lime, but they are too young to have formed any marked accumulation of this material in definite horizons, although in places there is a slight compaction due to lime carbonate at about the second foot. At about this depth the material effervesces vigorously with acid, the effervescence diminishing above and below. The old valley-filling materials, derived principally from coarse-textured rocks, and transported only short distances from their place of origin, have given rise to coarse-textured soils of the Superstition series.

The surface soils and subsoils of the Superstition series are of light-gray to light brownish-gray color and low organic-matter content. They are porous and of low water-holding capacity. The types are derived from old desert-stream and surface-wash deposits, with locally included coarse sandy and gravelly materials representing remnants of bars and beaches of former lakes or partially enclosed bodies of water. The surface is generally smooth and gently sloping, but in places it is wind blown and hummocky or somewhat eroded. Surface and internal drainage are excessive. The soils support only a growth of scattering desert plants and generally lie above the sources of water for irrigation.

In this survey the materials are apparently of somewhat more recent deposition than in the Imperial and Palo Verde Valleys, and in places fresh material is being added by infrequent wash from near-by mountain slopes. Along the west side of the valley they are derived almost entirely from granite and rocks of like character, whereas along the east and north sides they include a variety of materials eroded from partially consolidated sedimentary deposits which flank this part of the valley. The most typical development is found on the old beach line which encircles the valley. Five types of the series are mapped. They occupy the entire section between the valley floor and the mountains, an almost continuous strip 2 to 3 miles wide along the east and west sides of the valley.

As mapped in this survey the soils of this series include many narrow washes containing gray, loose, porous coarse sand and gravelly coarse sand, devoid of organic matter, and containing little lime. This material is of more recent origin and is more typical of the Carrizo series of soils as recognized in the survey of the El Centro

area.<sup>7</sup> The strips, however, are too narrow to be differentiated on a map of the scale used.

The soils derived from recent-alluvial materials are the most important in the area, both in extent and agricultural value. They occupy the floor of the valley and consist principally of light-colored sediments washed into the valley by the Whitewater River and other small streams issuing from the mountains at the northwest end of the valley. After exceptionally heavy rains in the mountains considerable areas of these soils in the vicinity of Indio and Coachella were still being flooded until a few years ago, when a levee was constructed through the lower parts of the valley. With each overflow a new deposit was left on the surface, resulting in the formation of a group of soils showing great irregularity as to stratification. They are without noticeable horizons of clay accumulation, compaction, or of concentration of lime carbonate at any point in the profile. However, definite horizons of structure occur wherever alkali is concentrated on the surface. These may take the form of a thin surface crust underlain by a thin, mellow, subsurface mulch; or the surface material may be flocculated, loose, and fluffy, with a fairly compact horizon immediately underneath. Below this the frequently changing strata are due primarily to the processes of deposition rather than to those of weathering or soil development. The soils of this group are represented by the Indio series.

The Indio series consists of irregularly stratified soils and subsoils without uniformity in the development of horizons, in the texture or thickness of strata, or in the order of their occurrence. In the virgin condition they are light gray, brownish gray, or light grayish brown when dry, and darker gray, slaty gray, or grayish brown when wet. The soils average low in organic matter, are highly micaceous, and are abundantly supplied with lime. The lime is very evenly distributed throughout the soil profile, as all of the horizons and strata effervesce freely with hydrochloric acid and no pronounced concentrations are visible in any part. In addition to the lime of mineral origin, there is a considerable reserve supply in the form of small fresh-water shells and shell fragments which occur scattered on the surface and distributed throughout the soils to depths of many feet.

The soils of the Indio series are derived mainly from granitic or quartz-bearing rocks. The soils occupy a generally flat valley floor with a fall of about 20 feet to the mile. Along the outer margins of the valley where the soils are lighter textured and the surface has been modified by winds, the topography is billowy with dunes 1 to 3 feet in height. Here both surface drainage and underdrainage are excellent. In the lower, flatter parts of the valley the fall is still sufficient for irrigation and surface drainage, and the pervious strata in the subsoil are favorable to underdrainage. In some of the areas containing a high content of alkali the soils are suffering from a high water table. The soils of the Indio series occupy a treeless desert, the only vegetation being mesquite, creosote bush, and other desert shrubs. They are adapted to irrigation and constitute a considerable proportion of the land under cultivation.

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<sup>7</sup> Soil Survey of the El Centro area, Calif. Field Operations of the Bureau of Soils, 1918.

The lake-laid soils are confined to an area covering several square miles along the shore of the Salton Sea, and have been only recently exposed by the recession of the Salton Sea. The materials are of mixed origin; they include sandy, micaceous deposits which resemble the Indio and Coachella series and are undoubtedly derived from the same granitic sources, together with purplish or chocolate-colored materials which appear more closely associated with Colorado River deposits. These purplish materials could properly be correlated with the Imperial or Holtville series of soils as recognized in the soil surveys of the Imperial Valley,<sup>8</sup> but being of small extent and of little agricultural importance, they are not shown separately on the map. The soils of the lake-laid group are included in the Woodrow series.

The soils of the Woodrow series consist predominantly of gray stratified soils and subsoils. The most characteristic feature is one or more layers of gray or drab, plastic, relatively impervious clay. These layers vary from only a few inches to 3 feet or more in thickness and may occur either at the surface or as distinct strata at various depths in the subsoil. Where a layer of considerable thickness occurs at the surface, the subsoil is predominantly light textured, consisting usually of gray or brownish-gray, micaceous fine sand. In places, however, the porous sandy subsoil is broken by one or more strata of gray, plastic clay, which have no uniformity in arrangement or thickness. As mapped in the Coachella Valley, the series includes strata of purplish or chocolate-colored clay. These layers are also very irregular in occurrence, in places forming the greater part of the lower half of the profile, and elsewhere occurring as thin layers near the surface.

The light-textured types are loose and friable. The soils of this series are, however, compact, low in organic matter, calcareous, and high in alkali. In many places the salts have accumulated on the surface, forming a brittle crust one-fourth to one-half inch thick, below which there is a very thin layer of flocculated, powdery material showing many salt crystals. The sandy soils are slightly dune-like or hummocky, but in general the topography is nearly level and favorable for irrigation. The soils, however, are poorly drained, with a water table ranging from a few inches below the surface near the lake to 6 feet in depth a few miles back. They are mostly bare of vegetation and undeveloped.

The wind-blown soils constitute an important group occupying considerable areas on both the east and west sides of the valley. They are among the youngest soils in the valley, the surface materials being still in the process of redistribution by winds. The group includes dunesand and two types and two phases of the Coachella soils.

The Coachella series includes types with medium-gray to brownish-gray or light-gray, loose, micaceous surface soils, low in organic matter, and gray to brownish-gray, micaceous subsoils, usually of similar texture and structure to many feet in depth. Although in general aspect the dry soil materials are of gray to brownish-gray color, upon close inspection they are observed to be of mixed or

<sup>8</sup> Soil Surveys of the El Centro and Brawley areas, Calif. Field Operations of the Bureau of Soils, 1918 and 1920.

pepper-and-salt color, consisting of light-colored quartz grains and dark-colored mica flakes or other dark-colored minerals. Locally the subsoil contains one or more strata of finer-textured, compact material; but these are not common, the soils under irrigation being typically porous and permeable and requiring considerable water for best results. When moist, the soils and subsoils are light brown. Small fresh-water shells and shell fragments are locally abundant on the surface and are irregularly distributed throughout the soil profile. The surface materials are only feebly calcareous or non-calcareous, but apparently the entire soil section below is well supplied with lime, although there are no visible concentrations except in the form of shells. Excepting small bodies near Salton Sea, the soils are practically free from alkali.

The soils of the series have been derived from wind-blown materials of granitic character which were originally carried into the valley by the Whitewater River and other streams issuing from the mountains following heavy storms. Since being deposited they have been carried eastward and southward by the strong winds that enter the valley through the San Gorgonio Pass, with the result that they now occupy a number of long strips along both sides of the valley. In places the sands are moving at the rate of several feet a year and locally are encroaching on the finer stream-laid deposits. The surface is typically wind-blown, with hummocks and dunes 3 to 10 feet in height. The soils have accumulated under low rainfall and support a scant vegetation of creosote bush, mesquite, and other desert shrubs.

In addition to the soils included under the soil series as described above, two types of miscellaneous materials of nonagricultural character were mapped. These are dunesand and rough broken and stony land.

At the time of the earlier survey of the Indio area (1903), information pertaining to methods of soil classification and the relationship of the various soils of this region was much less complete and most of the soils were correlated with the Fresno series. In the present survey, which was made in much greater detail and has had the benefit of accrued experience and information, these have been correlated as soils of the Superstition, Indio, and the Coachella series. The soils formerly mapped as types of the Imperial series have been largely divided between the Woodrow and the Indio series.

The following table gives the name, acreage, and proportionate extent of each type of soil mapped in the Coachella Valley area:

*Areas of different soils*

Soil	Acres	Per cent	Soil	Acres	Per cent
Coachella fine sand.....	33,728	19.2	Superstition gravelly sand.....	10,496	4.8
Smooth phase.....	8,512		Woodrow clay.....	9,152	4.2
Rough broken and stony land.....	27,712	12.6	Superstition sand.....	8,704	4.0
Superstition very stony sand.....	18,816	8.5	Dunesand.....	8,448	3.8
Indio very fine sandy loam.....	16,128	7.3	Indio very fine sand.....	7,808	3.5
Superstition stony sand.....	14,848	6.7	Superstition gravelly coarse sand.....	5,632	2.6
Indio loam.....	14,400	6.5	Indio clay.....	4,672	2.1
Coachella very fine sand.....	6,848	5.8	Woodrow loam.....	4,096	1.9
Smooth phase.....	6,016		Woodrow fine sandy loam.....	1,920	.9
Indio clay loam.....	3,648	5.6	Total.....	220,160	-----
Silty phase.....	8,576				



S. 11761

FIG. 1.—TOPOGRAPHY, DESERT VEGETATION, AND STONES ON SUPERSTITION  
VERY STONY SAND



S. 14400

FIG. 2.—SEVEN-YEAR-OLD GRAPEFRUIT ORCHARD ON SUPERSTITION SAND

Trees grown under irrigation and without fertilization until present year (1923). Recently irrigated; note furrows for distributing water





## SUPERSTITION VERY STONY SAND

The soil and subsoil materials of the Superstition very stony sand consist of light brownish-gray or gray, medium to coarse sand, in which sharp angular particles predominate. Embedded in this and scattered over the surface are excessive quantities of stones or boulders, accompanied by cobbles and gravelstones of various sizes. These are mainly of granitic rocks, including gneiss and micaceous schist, with occasional sandstone fragments, and are generally angular or only slightly abraded or waterworn. (Pl. 19, fig. 1.) The soil material is micaceous, very low in organic matter, and permeable and porous throughout the soil profile, with only a feebly developed horizon of compaction in the subsoil in areas of typical development.

The Superstition very stony sand is similar in character of soil material to the Superstition stony sand, except that the stones are larger and more abundant. There is no definite boundary between the two, the stones gradually increasing in number and size toward the mountains until they preclude all possibility of agricultural development. On the higher part of the alluvial fans they are several feet in diameter and occupy the surface almost to the exclusion of fine earth.

The type is very extensive. The largest body, containing about 15 square miles, occupies the upper fans extending from a point 2 miles west of Bendel to the San Diego County line. Other bodies occur west of Ensign School, in the embayment of the mountains 4 miles south of Point Happy, east of Coachella and northwest of Indio.

The surface ranges from gently sloping to steeply sloping. Drainage is excessive. On the higher part of the fans the vegetation consists of ocotillo, cholla, tassojia, and other drought-resisting, desert plants; and on the lower slopes, creosote bush, with palo verde in the washes. The land lies above sources of water supply for irrigation, and owing to this and to its coarse leachy texture and stony character, it has no value for agriculture.

## SUPERSTITION STONY SAND

The soil and subsoil of the Superstition stony sand, to a depth of many feet, consist of gray or light brownish-gray, medium to coarse sand containing waterworn gravel, cobbles, and stones. The coarse materials are chiefly granitic, with some gneiss, schist, and soft sandstone materials on the east side of the valley. The gravel is rather coarse, ranging from one-fourth inch to 3 inches in diameter, and the cobbles and stones usually range from 3 inches to about 1 foot in diameter. The stones increase in number and size toward the mountains and the more stony areas of the Superstition very stony sand. The entire profile is loose, porous, and droughty.

The Superstition stony sand is rather extensive. It occupies strips bordering both the east and west sides of the valley. Typical bodies occur along the base of the mountains on the east side in the northern part of the area and east of Mecca; and prominent areas parallel the Los Angeles-Brawley Highway on the west side of the valley from a point about  $1\frac{3}{4}$  miles west of Bendel to the Imperial County

line. The surface is sloping and considerably eroded by washes. Drainage is excessive. None of the land is farmed.

This soil is of loose, leachy character and low water-holding capacity, and has little agricultural value. If water becomes available for irrigation at a reasonable cost, some of the less stony areas could be utilized for the production of grapefruit, but so long as lands requiring less water for irrigation are available at a more reasonable cost for development, it is doubtful if any of this soil will become of agricultural importance.

#### SUPERSTITION GRAVELLY COARSE SAND

The Superstition gravelly coarse sand consists typically of gray or brownish-gray, gravelly sand extending to a depth of 6 or more feet. The structure varies with the age of the material. Between the numerous washes, where the deposits are older and therefore more typical of the series, the surface layer of an inch or less is slightly firmer than the material underneath, although this horizon is only imperfectly developed because of the comparatively recent age of the deposits. Generally the type, as occurring in the Coachella Valley, is loose and porous throughout. Locally there are stones 3 to 10 inches in diameter on the surface, and these are of common occurrence in the subsoil. The larger stones and cobbles are mainly of granite and similar rocks and the gravel consists principally of quartz fragments ranging from the size of rice grains to 2 or 3 inches in diameter.

Included with the type are several low narrow ridges comparatively free of gravel, in which the soil, below the surface inch, has about the same texture and structure as loose rice grains. These deposits represent old beaches and subsidiary strands which have undergone but little change since they were deposited.

Other inclusions consist of the numerous washes in which the soil is slightly grayer, looser, less calcareous, and more recent than typical. The washes are always narrow, but in places are so numerous as to constitute a large proportion of this land. This material is considered more typical of the Carrizo series, as recognized in previous surveys, but because of the small size of the individual bodies it was not practicable to separate them on the map. They are not confined to any particular locality, but occur throughout generally.

The Superstition gravelly coarse sand is of small extent and is confined principally to narrow bodies on the east edge of the valley, occurring intermittently from a point 3 miles east of Coachella southward to the southeast corner of the survey. The largest body is at Mortmar. A small area is northeast of Indio. Other small areas occur on the west side of the valley west of Ensign School and northwest of Oasis School. The surface is gently sloping, gently rolling, or ridgelike. The type represents the material of an ancient beach line that at one time more or less completely encircled both the Coachella and Imperial Valleys, but which, in the Coachella Valley, has been largely washed away by the many watercourses issuing from the mountains. Both surface drainage and under-drainage are excessive.

The soil is undeveloped and supports a scant growth of creosote bush and similar desert shrubs. It is of no agricultural value, having

an unfavorable location and topography, in addition to being too gravelly, coarse, and porous for successful irrigation and cultivation.

#### SUPERSTITION GRAVELLY SAND

The surface soil of the Superstition gravelly sand consists of 8 to 12 inches of light-gray or light brownish-gray sand containing large proportions of coarse and fine sands and a quantity of waterworn gravel ranging from one-eighth inch to 3 or 4 inches in diameter. The structure is usually loose and porous, but in a few areas on the east side of the valley there is a surface crust about one-fourth inch thick and slightly more compact than the underlying material. The subsoil is variable, but typically it is gray or light brownish gray in color, medium to coarse textured, and contains rather large quantities of gravel, cobbles, and bowlders, the stones ranging from 6 to 10 inches in diameter, increasing in size with depth. Both the coarse and fine materials are of granitic origin, the sand grains being sharp and angular, and many of the stones, having been transported only short distances, are somewhat angular.

Along the lower margins of the fans, where the soil merges into soils of the Indio series, the material is irregularly stratified from the surface downward. Strata or lenses of light-gray, compact loam or silty loam varying from a fraction of an inch to 1 foot thick are of irregular occurrence, in places being numerous enough to give the soil a close resemblance to the Indio soils. The surface soil, however, is always gravelly and characteristic of the materials that compose the soils of the Superstition series.

The surface soil is mildly calcareous; the lime content increases downward to about 24 to 30 inches, below which it apparently diminishes, some of the coarse, deeper strata showing only a slight effervescence with acid. Even at the depth of strongest concentration lime accumulations are not usually visible and appear to have effected little change in the structure of the soil. This soil is practically free from alkali.

The Superstition gravelly sand is confined principally to the eastern margin of the valley where an almost continuous strip one-fourth to one-half mile in width separates the wind-blown fine sands of the Coachella series from the higher-lying stony or coarse-textured Superstition soils of the alluvial fans. One small body occurs on the west boundary of the area south of Palm Springs Road.

Most of the land lies at about the same elevation as the ancient beach line, or a little below it. The surface slopes gently toward the valley and is cut by numerous washes, giving excellent surface drainage. Owing to the porous subsoil, underdrainage is excessive.

The type is unimportant at present, as less than 40 acres are in cultivation. The native vegetation consists of a scattering growth of creosote bush, with other small desert shrubs, and a few mesquite. Water is not available for most of the type, but in case it is developed from any source the soil should be fairly well adapted to alfalfa and probably to grapefruit. Its position is such that it is probably as immune from frost as any soil in the valley. Owing to its porous structure, it requires much water for irrigation and only low yields of ordinary crops can be expected.

## SUPERSTITION SAND

The Superstition sand, in the virgin condition, consists of 6 to 12 inches of light-gray to light brownish-gray, open-structured sand, containing large quantities of both coarse and fine sand, grading into loose coarse sand of similar color. At an average depth of about 40 inches the subsoil passes into gray, porous, somewhat coarser sand containing a small quantity of fine granitic gravel. The soil material is almost entirely devoid of organic matter. It absorbs moisture readily but has a low capacity for retaining water. The type is mildly calcareous throughout its entire depth and is usually free from alkali. When wet the color becomes light brown, and under irrigation a thin layer of loamy material is sometimes formed under the surface.

This type of soil, as mapped, includes a number of variations. For example, in that part of the area where the soil adjoins the higher-lying soils of the Superstition series, the surface is covered in places with fine granitic gravel and the subsoil frequently contains granitic rocks 3 to 10 inches in diameter. The soil in these areas grades toward the Superstition gravelly sand, but being less gravelly and less porous, it has a slightly higher value than the typical gravelly sand. In places the subsoil contains one or more strata of ashy-gray material similar to that which underlies the soils of the Indio series. Occurring as it does, however, on the margin of the valley floor, where each heavy rain brings fresh material from the higher-lying fans, the greater part of the profile more nearly resembles that of the Superstition series. The type as mapped includes also a number of desert washes, ranging from a few feet to 100 feet or more across, filled with gray, coarse, sharp sand, porous and leachy, and frequently containing gravel. This material is similar to the soils of the Carrizo series, but is found in such small bodies that it was impracticable to differentiate it on the map.

Along the east side of the valley this type tends to be more compact than along the west side. An area on the Blythe Road 3 miles east of Mecca consists of irregularly stratified materials ranging in texture from coarse gravelly sand to silt. In places there are as many as 30 distinct strata; in some places all are exceedingly compact, and in near-by areas the subsoil may contain several strata showing no compaction whatever. Here and there in this vicinity the surface is covered with one-half inch to 1 inch of gray, very compact silty material deposited by recent overflows of drainage ways issuing from the mountains. The surface of the soil in these compact bodies is baked so hard that it is difficult to penetrate it even with a pick.

The Superstition sand is moderately extensive. The largest area, varying from a narrow strip to  $1\frac{1}{2}$  miles in width, extends for about 10 miles in a northwest-southeast direction through Oasis. Two other bodies, each containing about 1 square mile, are near the northwest corner of the survey. Here the soil is associated with dunesand, the surface is somewhat billowy or ridged, the vegetation is very scant, and the soil is being drifted by winds. Elsewhere the surface is smooth or only slightly wind blown, and leveling could be done without much expense. Drainage is good to excessive.

The Superstition sand has only local importance at the present time, as only about 1 per cent of it is under cultivation. The culti-

vated areas are in the vicinity of Oasis. Grapes and grapefruit are the principal crops. Seven-year-old grapefruit trees on this type of soil are said to have averaged about 200 packed boxes per acre for each of the last two years. The fruit is of excellent quality and demands a high price. The groves are irrigated, given clean cultivation, and until this year have not been fertilized. The trees are healthy and have made a vigorous growth. (Pl. 19, fig. 2.) Both the Malaga and Sultanina (Thompson Seedless) varieties of grapes are grown on this soil. The grapes ripen early, have a high sugar content, and are said to stand shipping better than those grown on some of the heavier soils. Yields range from 150 to 250 crates per acre.

Well-improved vineyards and citrus groves on this type of soil are held at \$1,000 to \$2,500 or more an acre. Unimproved land suitable for these crops can be bought for \$40 to \$100 an acre.

Because of the porous structure and low content of organic matter, this soil requires considerable water for best results. However, it is early, easily cultivated, well drained, and free from alkali. Its water-holding capacity would be improved by the addition of organic matter. The typical soil is well suited to the production of grapefruit and grapes. It is also suited to early vegetables, although the yields, without fertilization, will not be so high as those obtained from the slightly heavier soils. The included compact variation has no present value for agriculture.

#### INDIO VERY FINE SAND

The surface soil of the Indio very fine sand in the virgin condition, consists of about 8 inches of light brownish-gray, firm, very fine sand or loamy very fine sand, which has a small percentage of organic matter, is rich in lime, and usually contains moderate to large quantities of alkali. Under moist field conditions the soil is loamy in character and resembles in physical condition a fine sandy loam. In places where the salts have accumulated on the surface they have formed a thin salt crust, below which there is a thin darker-colored horizon with a friable, granular structure. The combined thickness of these two horizons rarely exceeds 1 inch. The subsoil is irregularly stratified and has little uniformity. The upper part frequently consists of gray or brownish-gray, friable fine sandy loam or very fine sandy loam to a depth of about 16 inches, where it passes abruptly into gray, or sometimes faintly pinkish-gray, compact loam, heavy fine sandy loam, loam, clay loam, or silty clay. The thickness of this layer varies from a few inches to 1 foot or more. The deeper subsoil, to a depth of 6 feet or more, is usually gray, firm, but permeable fine sandy loam, although it may contain one or more thin strata of heavier material. In places the greater part of the profile is made up of very thin strata of fine sandy loam and material of heavier texture. All of the strata effervesce freely with acid, and all contain varying quantities of alkali, the alkali almost invariably being most abundant at the surface.

The type has a rather small extent. Most of it occurs in the vicinity of Thermal. There are small bodies east of Indio, west of Indian Wells, near Westside Church and Ensign School, in the vicinity of Mecca, Caleb, and Oasis School, and near the shore of Salton Sea west of Mortmar.

The topography in general is smooth, but the surface in places has been modified by winds which have blown the lighter-textured material into dunes 1 to 3 feet in height, leaving small, level depressions intervening. In general the topography is favorable for irrigation, and leveling should be comparatively inexpensive. In the northern part of the area both the surface and internal drainage are good. Near the Salton Sea the underdrainage is deficient, as ground water stands within 1 to 3 feet of the surface. Near Thermal water was encountered in borings at 5 to 7 feet.

The Indio very fine sand has at present only local importance, about 10 per cent of it being under cultivation. The cultivated areas are mostly near Thermal, Westside Church, and Ensign School and on the Palm Springs Road at the west boundary of the survey. At the last-named location an excellent date orchard and some young vineyards are established. Elsewhere the principal crop is onions, with some dates and grapes east of Thermal. The undeveloped tracts support a rather vigorous growth of creosote bush, mesquite, hop sage, arrow weed, atriplex, and pickleweed. The land is handled in about the same manner as the Indio very fine sandy loam, and where similar alkali conditions exist the yields are about the same.

Unimproved land of this type can be bought for \$15 to \$100 an acre, depending on the content of alkali. Tracts developed for ordinary crops command \$250 to \$300 an acre, and well-developed date orchards are held at \$3,000 to \$4,000 or more.

A number of areas of this soil type near the Salton Sea, near Thermal, and east of Indio are strongly affected with alkali. In their present condition these areas are unsuited to ordinary crops, although with special methods of planting some of them may be found suitable to date palms. Where the soil contains only small quantities of alkali it is well adapted to alfalfa, grapes, onions, and other truck crops.

The following table shows the results of mechanical analyses of samples of the soil, upper subsoil, and lower subsoil of the Indio very fine sand:

*Mechanical analyses of Indio very fine sand*

Number	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
576001	Soil, 0 to 3 inches.....	0.3	0.8	1.4	27.6	59.3	6.1	4.7
576002	Subsoil, 3 to 16 inches..	.2	.5	2.6	27.0	47.6	14.5	7.9
576003	Subsoil, 16 to 24 inches	.2	.4	.9	11.9	41.8	30.1	15.0

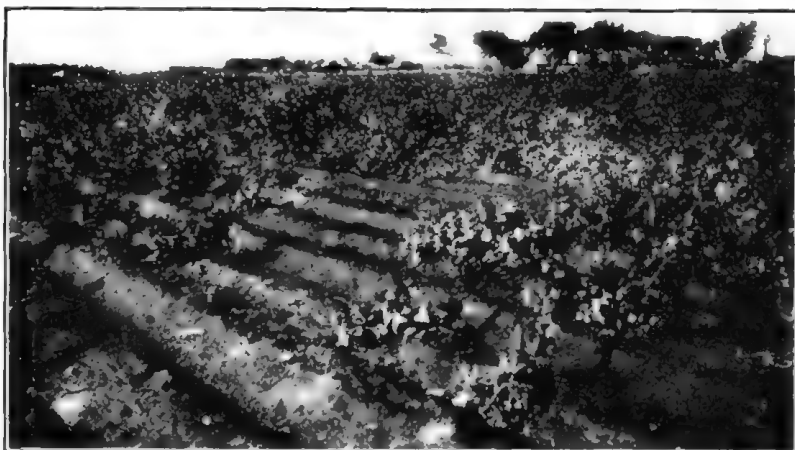
#### INDIO VERY FINE SANDY LOAM

The surface soil of the Indio very fine sandy loam consists, in the virgin condition, of a surface horizon one-fourth inch to 1 inch thick, of light-gray mellow very fine sand or very fine sandy loam containing a small quantity of organic matter, and a second horizon of gray, highly micaceous very fine sandy loam, 4 to 6 inches in thickness, slightly firm but permeable, containing a good supply of lime, low in organic matter, and usually carrying a small quantity of soluble



S. 14503

FIG. 1.—EROSION AND STRATIFICATION OF INDIO VERY FINE SANDY LOAM



S. 14504

FIG. 2.—VIEW SHOWING SPOTTED GROWTH OF COTTON ON STRONGLY AFFECTED ALKALI LAND, WOODROW FINE SANDY LOAM





salts. The material tends to be of light texture and approaches the Indio very fine sand, into which it grades. The subsoil is irregularly stratified and variable. (Pl. 20, fig. 1.) Locally it consists of gray or brownish-gray, loose, micaceous very fine sand extending to a depth of about 36 inches, underlain by gray or brownish-gray, highly micaceous very fine sandy loam of firm structure to a depth of 6 or more feet. Frequently the subsoil contains one or more strata of gray, moderately compact loam or light clay loam.

There is no uniformity in the thickness or arrangement of these heavier-textured materials; a layer may be only a fraction of an inch thick in one place and near by the same layer may attain a thickness of a foot or more. All of the strata in this soil type effervesce freely with dilute hydrochloric acid. There is a profusion of small freshwater shells and shell fragments throughout both the soil and subsoil, but there is no visible accumulation of lime carbonate and apparently no marked lime cementation in any part of the profile. Where soluble salts occur they are principally in the surface materials, the pervious subsoils being comparatively free.

Under cultivation the surface layers become mixed and present a uniformly gray appearance, changing to a brownish gray when moist. The soil remains friable and mellow to the depth of cultivation, but under irrigation, or where subjected to packing, such as in roads or paths, there frequently develops immediately beneath the plow depth a compact, dense, less pervious layer varying from 1 inch to 5 or 6 inches in thickness. This material is light gray or ashy gray in color, highly micaceous, and calcareous, but usually has only a small content of other mineral salts. The development of this condition is undoubtedly encouraged by the presence of lime and some alkali salts, but it seems also to have been intensified by the rearrangement of the flat flakes of mica, which, under irrigation, have a tendency to assume a horizontal position, overlapping like shingles on a roof. The resulting structure is so unfavorable to the downward passage of water that the material of this horizon sometimes remains dry and powdery for hours after water has been applied. This horizon is never continuous over any considerable area, but occurs in patches scattered through the fields.

The Indio very fine sandy loam occurs in a number of small bodies lying principally between the lower parts of the valley and the slightly higher lying areas of wind-blown soils of the Coachella series. The most important bodies are in the vicinity of Indio, Coachella, Bendel, and near the Oasis and Ensign Schools. Two strips, varying from one-eighth to one-fourth mile in width and 3 miles in length, skirt the outer margin of the valley east of Coachella and Thermal.

In the vicinity of Martinez and southwest of this point along the margins of the alluvial fans, the surface soil is coarser than typical and is locally underlain at 8 to 10 inches by gray, compact, medium and coarse sand. The coarse material sometimes extends to a depth of 6 feet or more but is more often broken by one or more strata of gray, compact loam.

The surface of the Indio very fine sandy loam is usually smooth, requiring little leveling for irrigation. In places, however, it is

covered with low wind-blown mounds, the crests of which are nearly always lighter in texture and more porous than other parts of the type area. In most places both the surface and internal drainage are excellent. In the spots where a compact layer occurs beneath the surface, penetration is slow, and sometimes several hours more are required to irrigate these spots than other parts of the fields. Generally speaking, the water table is not encountered on this type within less than 6 feet of the surface. The only exceptions are a few small patches adjacent to artesian wells, where water has been allowed to flow continuously for some time, and along the highway about  $1\frac{1}{8}$  miles north of Bendel.

The Indio very fine sandy loam is one of the most important soils in the Coachella Valley. About 60 per cent of it is under irrigation and the rest is covered by a vigorous growth of mesquite, creosote bush, and a number of other small desert shrubs. Practically every crop produced in the valley is grown on this soil. The largest acreages are devoted to onions, cotton, grapes, and dates. Among the other crops of local importance are alfalfa, small grains, peas, beans, tomatoes, sweet corn, grapefruit, and figs. All of these products are grown as cash crops, except alfalfa and small grains, which are fed on the farms. All of the vegetables are grown in the fall and winter and marketed in late fall, winter, or spring. In favorable seasons onions return 250 to 600 crates, with an average of about 300 crates; grapes, 200 to 450 crates, with an average of about 300 crates; and cotton, three-fourths to  $1\frac{1}{2}$  bales, with an average of about 1 bale per acre. Most of the date palms are still too young for full bearing, but a number of the groves 6 to 9 years old are yielding an average of about 125 pounds per palm, or about 3 tons per acre. In addition they provide some revenue from the production of offshoots. Alfalfa yields 5 to 10 tons, with an average of about 7 tons; wheat and barley hay, 1 to 3 tons, with an average of about 2 tons; and peas and beans 1 to 2 tons, with an average of about  $1\frac{1}{2}$  tons per acre.

The vineyards on this soil are usually given clean cultivation. Between irrigations the soil is cultivated frequently to maintain a dust mulch. After harvest, which is usually finished by the middle of July, the vines are again irrigated. This usually carries them through until after pruning, although they are sometimes watered once in the fall. A few acres of peppers are grown under canvas southwest of Coachella and in the vicinity of Oasis, and other areas of this crop are grown in the open in the vicinity of Indio and Oasis.

Undeveloped land of Indio very fine sandy loam sells for \$150 to \$200 an acre. Areas developed for general farming sell for \$200 to \$400 an acre, vineyards at \$1,000 or more an acre, and date groves for \$3,000 to \$4,000 an acre, although many of the better groves could not be bought for less than twice these figures.

The Indio very fine sandy loam is one of the best soils in the Coachella Valley. It is well adapted to practically every crop which the valley produces. Being easily cultivated and somewhat more productive than the coarser-textured sandy types, it is highly prized for the production of onions, truck crops, grapes, and dates. It is well drained, comparatively free from alkali, and has a high water-holding capacity, which enables it, if properly cultivated, to go

longer than most of the other soils between irrigations. The soil, however, is not quite so early as the lighter-textured types. For those areas in which a compact layer has developed beneath the surface deeper cultivation and the application of barnyard manure or the turning under of green-manure crops are recommended.

#### INDIO LOAM

The profile of the Indio loam is very irregular, being made up of alternating strata which have little uniformity in texture, thickness, or the order of arrangement. The structure also varies considerably with the content of salts. In general, where the content of alkali is high, the profile is as follows: A thin surface horizon of brownish-gray alkali crust one-eighth to one-fourth inch thick; a subsurface mulch consisting of gray or brownish-gray friable or granular loam containing salt crystals, extending 2 to 3 inches in depth; and a third horizon of the same color consisting of micaceous compact loam extending 20 to 36 inches in depth. These materials are of rather light loam texture, and as mapped the type may include some areas of fine sandy loam. The underlying material consists of alternating strata of gray, micaceous very fine sandy loam or very fine sand, silty loam, clay loam or silty clay, the heavy-textured layers usually being mottled with rusty brown. In places the subsoil consists principally of heavy-textured material, whereas in near-by areas sandy material predominates, the changes occurring so irregularly that it is not practicable to separate them on a map of the scale used in this survey.

In areas not seriously affected with alkali, horizons due to soil development are less apparent, although thin strata due to deposition are very common. In cultivated fields the surface soil is mellow to the depth of cultivation, but immediately below this depth there frequently develops a compact horizon of ashy-gray, silty, highly micaceous material which offers considerable resistance to the downward passage of water. Examples of this condition are seen in the town of Coachella, where the loose surface soil has been removed by winds, leaving the denser material exposed. Usually the Indio loam has the appearance of very fine sandy loam, but when slightly moistened it becomes cohesive and plastic, showing the effect of a rather high content of silt and clay. The soil is deficient in organic matter, is apparently rich in lime, and all parts of the profile contain varying quantities of other mineral salts.

The Indio loam is rather extensive. It occurs in a number of strips one-fourth to one-half mile in width and 2 to 6 miles in length extending generally in a northwest-southeast direction from a point about 5 miles northwest of Indio to 3 miles southeast of Mecca. An important body occupies a flat at the base of the mountains west of the Union High School.

The surface is usually flat and favorable for irrigation. Especially level areas adjoining the mountains on the west side of the valley. Here the surface is playalike, resembling an old lake bed, with drainage imperfectly developed. In places, notably in small bodies east of Coachella, the surface is modified by scattered wind-blown dunes 2 to 3 feet in height. Between the dunes are

small level spaces of heavier material which have been flooded within recent years by overflows from the Whitewater River. In general, however, the land has fairly good drainage through previous strata in the subsoil.

Although only 10 to 15 per cent of the Indio loam is under cultivation, the type has considerable local importance. The greatest development is found in the vicinity of Coachella. The principal crops are onions, cotton, grapes, dates, and alfalfa, but practically every crop common to the valley is grown on the type. The alfalfa, milo, wheat, barley, and oats are fed to work stock on the farms, and all the other products are sold as cash crops. Vegetables, principally peas and beans, are grown in small quantities and marketed in the winter and early spring.

Onions yield 250 to 500 or more crates, with an average of about 300 crates per acre. Cotton returns three-fourths to  $1\frac{1}{2}$  bales, with an average of about 1 bale; grapes 200 to 450 crates, with an average of about 275 crates, and alfalfa an average of about 1 ton per cutting, or 5 to 10 tons for the year. Most of the date palms are still young, but the average yield for those in bearing is probably around 3 tons per acre. Milo yields one-half to 1 ton of grain; wheat, barley, and oats yield 1 to 3 tons of hay; and green peas and beans produce an average of about  $1\frac{1}{2}$  tons per acre.

This type of soil is handled in the same manner as the Indio very fine sandy loam. A large proportion of the cotton fields are allowed to volunteer, the second crop growing from the cut stalks of the previous season, thus effecting a considerable saving on labor and seed.

Unimproved areas of the Indio loam can be bought for \$15 to \$100 an acre, depending on the content of alkali. Irrigated tracts improved for general farming sell for \$250 to \$400 an acre, vineyards at \$1,000 or more, and date groves of good varieties command \$4,000 to \$6,000 an acre.

Where this type is comparatively free of alkali it is considered one of the better soils for staple crops in the valley. Yields usually range a little higher than on the soils of the Coachella series. However, this type of soil is a few days later than the Coachella soils, a little harder to cultivate, and more generally affected by alkali. A large proportion of it in the trough of the valley contains a surface concentration of 2 to 3 per cent, a quantity sufficient to preclude the growth of all cultivated crops. Under certain conditions of moisture and alkali, the soil has a tendency to form a thin crust on the surface and requires frequent cultivation for best results. This tendency to crust is due in part to the low content of organic matter, and the soil can be improved by turning under green-manure crops.

#### INDIO CLAY LOAM

The surface soil of the Indio clay loam, in the virgin condition, consists of a gray, brittle alkali crust about one-fourth inch thick, underlain by a gray, fluffy, or flocculated clay loam, strong in alkali, to a depth of about 3 inches. When dry, this is mellow and friable and has the feel of a fine sandy loam, but the clay content is enough to make it plastic and sticky when wet. This second horizon rests on

a gray, moderately compact clay loam extending 20 to 30 inches in depth, where it usually passes into gray, compact silty clay, which in turn gives place at various depths to gray, micaceous clay loam mottled with yellow and brown. The profile, however, is variable and may contain one or more strata of light-textured material, especially below a depth of 3 feet. All of the strata contain lime, and most of them contain quantities of other mineral salts.

Under irrigation and cultivation the surface horizons become mixed with the underlying material, and for a time thereafter the differences in the profile have the appearance of being due merely to deposition. However, if left unstirred the surface crust and sub-surface mulch reappear within a few months, their presence being due to the large content of alkali, which generally is most strongly concentrated near the surface.

This type is inextensive. The largest bodies occur in the trough of the valley south of Thermal. Another body occupies a narrow, winding flat at the base of the mountain 2 miles south of Point Happy, and a third occupies a small flat where the railroad crosses the west boundary of the area.

Agriculturally the Indio clay loam is the least important soil in the less elevated part of the valley. Less than 5 per cent of it is cultivated. Some of the fields in the vicinity of Thermal which have been irrigated in the past are now abandoned because of alkali, and some of the others still in use are giving poor returns. A few small fields of cotton are giving very low yields. Some fields are still being irrigated from artesian wells for the purpose of growing Bermuda grass and salt grass for pasturing horses and mules. The greater part of it is covered with atriplex, pickleweed, and other alkali-resisting plants.

The price ranges from \$15 to \$100 an acre, depending on alkali content and improvements.

Much of this type is nonagricultural because of excessive alkali. In places southwest of Thermal the water table stands at 3 to 4 feet beneath the surface, and practically all of the type is poorly drained. The soil is hard and impervious. If plowed when wet or before a hard rain, the soil runs together and puddles, remaining intractable for several years unless given a great deal of cultivation.

The area on the west boundary of the survey northwest of Myoma and the one south of Point Happy are hardly typical. They are thinly stratified and when wet are slightly yellowish in color. They contain little alkali and should be better adapted to all of the staple crops of the valley.

*Indio clay loam, silty phase.*—The surface soil of the Indio clay loam, silty phase, consists of a surface layer of 1 to 2 inches of gray, flaky, laminated, friable clay loam or silt loam, usually having a high content of mineral salts; and a second stratum, 10 to 12 inches deep, consisting of light-gray, smooth, compact clay loam of silty texture and containing a quantity of finely divided mica. The subsoil is composed of irregular strata 6 to 20 inches thick consisting of gray, compact loam, clay loam, or silt loam, and friable, micaceous very fine sand and very fine sandy loam. In places the heavy material predominates, whereas in other places the sandy material

composes the major part of the profile. All of the strata are calcareous and contain varying quantities of alkali salts.

In some places, principally near Indio, where storm waters have flooded the land within recent years, the surface is covered with a new deposit of light-gray, very compact silt 1 to 5 inches thick. When thoroughly dry this floury material bakes to an almost shale-like hardness, but in time becomes friable and granular under cultivation. Usually the soil has a rather high content of very fine sand which makes it mellow and easily worked.

Soil of this phase is of small extent, though more extensive than the typical soil, and is confined to the trough of the valley. The most important bodies parallel the railroad from a point  $3\frac{1}{2}$  miles northwest of Indio to a point  $3\frac{1}{2}$  miles southeast of Coachella. A body containing about  $2\frac{1}{2}$  square miles occupies the head of a shallow depression lying just south of the Ensign School. Another narrow strip lies northeast of Thermal.

The surface is smooth, with a gentle fall toward the lower part of the valley. Surface drainage is fairly good and little leveling is required for irrigation. Underdrainage is adequate except in an east-and-west strip running through the middle of the body south of Ensign School, where the water table stands 1 to 4 feet below the surface. In a large part of this body, as well as in the southern part of the body southeast of Coachella, the soil is strongly affected with alkali and of no value for ordinary crops in its present condition.

This soil has only a local importance. In the vicinity of Indio and Coachella the greater part of it is under irrigation, but elsewhere it is mainly undeveloped and covered with creosote bush and mesquite and, in the more salty areas, with atriplex, pickleweed, and arrow weed. Approximately 30 per cent of its total area is in crops. Onions occupy the largest acreage, followed by grapes, dates, alfalfa and barley hay, cotton, milo, sweet corn, and vegetables. An important acreage of grapefruit is being planted in the vicinity of Indio. The sweet corn is harvested in June and marketed in Los Angeles and San Francisco.

Where the soil contains not more than a trace of alkali, it returns as high yields of the staple crops as any soil in the valley. Grapes yield as high as 500 crates, with an average of about 300 crates per acre. Alfalfa returns 5 to 10 tons per season, or about 1 ton per cutting; and wheat, barley, and oats cut for hay, yield 1 to 3 tons per acre.

Undeveloped tracts of Indio clay loam, silty phase, can be bought for \$50 to \$150 an acre, and areas improved for general farming for \$200 to \$400 an acre. Well-improved vineyards and date orchards of good varieties command \$1,000 to \$3,000 or \$4,000 an acre.

The Indio clay loam, silty phase, is a productive soil and responds readily to fertilization and cultivation. If neglected, the surface has a tendency to bake, but if properly handled, the soil remains mellow and friable and in this condition has a high water-holding capacity. The application of barnyard manure or the plowing under of straw or green-manure crops improves the structure and reduces

the tendency to bake. Considerable areas of the soil phase are strongly affected by alkali, but where the salts are not too strong the soil is well suited to the production of all of the staple crops of the valley.

#### INDIO CLAY

The surface soil of the Indio clay consists, in the virgin condition, of a gray, hard, brittle alkali crust one-fourth to nearly one-half inch thick; a subsurface layer of gray, powdery, fluffy clay containing a quantity of salt crystals and extending to about 2 inches in depth; and a third horizon of gray, fairly compact clay extending to an average depth of about 8 inches. These materials are of high silt content and smooth texture, approaching a silty clay. The subsoil is irregularly stratified, with no uniformity in texture, structure, or order of arrangement of the various strata. Differences are apparently due to deposition rather than to any marked changes that may have taken place through weathering. The strata range from gray, micaceous fine sand or fine sandy loam to loam, silt loam, and clay. The sandy layers vary from a few inches to 2 feet in thickness and may occur in any part of the profile, although most commonly confined to below 3 feet. In places where the last 2 feet consist of clay, the color shows a slight pinkish cast at about the sixth foot.

When wet the color becomes brownish gray or grayish brown, some of the heavy-textured material being slightly greenish gray or drab. Under cultivation the surface horizons disappear, and whatever differences are seen appear to be due to deposition only. If plowed when in the proper state of moisture, the soil works up into a mellow condition, but if stirred when wet, it has a tendency to puddle and on drying becomes hard and intractable.

Apparently the entire profile is well supplied with lime and usually all of the various strata are high in alkali. Throughout the greater part of the type the salts have accumulated on the surface in such strength that the soil is practically worthless for ordinary crops.

The type is inextensive. One body, beginning  $1\frac{1}{2}$  miles south of Mecca, extends northwest along the railroad to within 2 miles of Thermal. Two other bodies occur between Thermal and Martinez. The type occupies the lowest part of the valley trough in the artesian belt of the valley and the water table is comparatively near the surface. The topography is nearly level, with a slight fall in the direction of the Salton Sea. It is favorable for irrigation, but provides only fair surface drainage, and the underdrainage is usually inadequate.

The Indio clay is unimportant agriculturally. Only about 2 per cent of it is cultivated, the chief crops being cotton and milo. Yields are low, because of the content of alkali. No recent sales of this type of soil are reported, but the price for undeveloped land is said to range from \$15 to \$25 an acre.

The greater part of the Indio clay is valueless for ordinary crops until reclaimed by drainage and leaching of the alkali salts. This process would call for large expense, which, from the individual landowner's standpoint, is not justified under the present conditions

in the valley. The reclamation of this part of the valley is a problem requiring concerted action rather than individual effort.

Results of mechanical analyses of soil and subsoil materials of the Indio clay, exclusive of the thin alkali crust, are given in the following table:

*Mechanical analyses of Indio clay*

Number	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
576023	Soil, $\frac{1}{4}$ to 8 inches.....	0.0	0.5	0.4	2.5	17.6	40.6	37.0
576024	Subsoil, 8 to 20 inches.....	.0	.4	.4	2.0	11.9	48.6	37.0

#### WOODROW FINE SANDY LOAM

The surface soil of the Woodrow fine sandy loam consists of 4 to 6 inches of gray or brownish-gray, loose fine sandy loam, low in organic matter and high in alkali salts. The subsoil is variable, but usually consists of gray or slightly pinkish-gray, plastic, compact clay, faintly mottled with yellow or rusty brown. This relatively impervious layer sometimes extends to a depth of 6 feet, but more commonly is only 1 to 2 feet in thickness and generally passes into a layer of light-textured material at 4 to 5 feet in depth. In places one or more strata of purplish or chocolate-colored clay are encountered. The clay layers have no uniform order of arrangement, ranging all the way from a few inches beneath the surface to the lowest part of the profile. All the strata are calcareous and all contain alkali. The strongest alkali accumulations, however, are on or near the surface, the first few inches usually containing more than 3 per cent.

Included with the type are a few small bodies in which the surface soil is a loose, fine sand. The soil in these localities resembles that of the Coachella fine sand, but the subsoil differs in having one or more strata of the clay characteristic of the Woodrow series.

The Woodrow fine sandy loam has a total area of 3 square miles. It is confined to four narrow bodies near the shore of Salton Sea. The largest, containing about  $1\frac{1}{2}$  square miles, is southwest of Caleb, and the others are south of Mecca and near the Imperial County line. The surface is slightly wind blown, with dunes 2 to 3 feet in height. Surface drainage is fairly good, but the water table is high, and the underdrainage is retarded by the impervious clay in the subsoil.

Only one small tract is cultivated. The rest is mostly bare or supports a scattering growth of pickleweed, atriplex, and other alkali-resisting plants. Cotton, onions, and tomatoes are being grown, but it is difficult to obtain a stand of cotton and the yields are low. (Pl. 20, fig. 2.) Owing to the high content of alkali and the unfavorable drainage conditions, the greater part of the land has no present value for agriculture.

#### WOODROW LOAM

The surface soil of the Woodrow loam, in the virgin condition, consists of a gray, brittle, cemented crust one-eighth to one-fourth inch thick; a second horizon of gray or brownish-gray, flocculated



or loose, powdery loam about one-fourth inch thick, showing a quantity of salt crystals; and a third horizon extending to 7 to 10 inches, consisting of brownish-gray, friable loam, locally containing a large quantity of very fine sand. Owing to the high content of alkali which is always present in this soil, the structure of the dry surface material immediately below the surface crust to a depth of several inches is usually loose, giving the type the appearance of a soil of lighter texture. The soil is low in organic matter. The subsoil is irregularly stratified. It commonly consists of brownish-gray, micaceous very fine sand or very fine sandy loam of permeable structure, passing at depths of 30 to 40 inches into a layer of light-gray, plastic, relatively impervious clay which either extends to 6 or more feet in depth or is interrupted by one or more strata of friable fine sand or purplish or chocolate-colored, compact clay. There is no uniformity in the thickness of the strata or in the order of their arrangement.

Practically all of the type is strongly affected with alkali. The salts are most strongly concentrated in the upper part of the profile, the surface few inches usually containing more than 3 per cent. All of the strata effervesce freely with acid, but the soil is too new to have accumulated the lime in definite horizons. Owing to imperfect drainage, yellowish or rusty-brown mottlings are of irregular occurrence in all parts of the soil profile.

The type is inextensive. Narrow strips, averaging about one-fourth mile in width, border the Salton Sea, and a long narrow body curves northwest across the flats south of Mecca. The surface, like that of the Woodrow clay, is apparently level, but there is a slight, uniform fall in the direction of Salton Sea. Near the shore the water table is only a few inches beneath the surface, but with the increase in elevation farther back it falls to 5 or 6 feet south of Mecca. Both the surface drainage and underdrainage are poor. The Salton Sea is being lowered by evaporation, and as the water recedes additional land is being exposed and the water table throughout all the soil is correspondingly lowered.

The land is undeveloped and of no present agricultural importance, owing to the high content of alkali and the poor drainage conditions. Most of it is bare of vegetation or sparsely covered with pickleweed and atriplex.

#### WOODROW CLAY

The Woodrow clay, as occurring in the Coachella Valley area, is somewhat variable in color and in the texture, structure, and arrangement of strata in the subsoil. The type consists usually of gray or light pinkish-gray compact clay 10 to 12 inches deep, overlying gray, plastic, exceedingly compact and relatively impervious clay extending to an average depth of about 30 inches. Below this the subsoil consists of alternating strata of varying thickness of gray and pinkish-gray compact clay. Locally the subsoil contains one or more strata of brownish-gray, micaceous, fine, or very fine sand. In places these light-textured strata are only a few inches in thickness, although a number of areas are included in which the lower half of the 6-foot depth is uniformly sandy and pervious. The type is strongly affected with alkali, a large proportion of which is concen-

trated in the upper 2 feet. Usually the content of the surface few inches is considerably in excess of 3 per cent. Under certain conditions of moisture the salts have cemented the soil particles and formed a brittle crust on the surface, below which there is a thin horizon in which the soil is flocculated and puffy or granular. Immediately underlying this, and within less than 1 inch of the surface, the soil is firm and compact. With a change in moisture content, either way, these structures disappear, the surface becoming firm and smooth with a structure similar to the underlying soil.

The Woodrow clay is confined to one body containing about 14 square miles adjoining the Salton Sea on the northwest. The topography is nearly level, like the floor of a lake, with a slight fall toward the sea. Both the surface drainage and underdrainage are inadequate. Near the sea the water stands within a few inches of the surface, the depth gradually increasing to 5 or 6 feet in the higher parts of the area. As the sea recedes by evaporation additional areas are being exposed and the water table is correspondingly lowered, but the presence of the layer of relatively impervious clay restricts the free movement of ground water and adds to the difficulty of drainage. Where the dense clay layer occurs near the surface and the subsoil is sandy, the land could probably be reclaimed by leaching out the salts. However, it would require an abundance of water and an expense which would not be justified under present conditions.

This type of soil is entirely undeveloped and, excepting a scattering growth of pickleweed, is bare of vegetation. In its present condition it is valueless for agriculture.

#### COACHELLA FINE SAND

The surface soil of the Coachella fine sand consists, in the virgin condition, of gray or brownish-gray, loose, incoherent, micaceous fine sand extending to an average depth of about 10 inches. The sand consists of a pepper-and-salt mixture of light and dark colored mineral particles. The soil is low in organic matter and is easily drifted by winds. The subsoil is variable, but most commonly consists of gray or brownish-gray, micaceous fine sand having the same loose, permeable structure as the surface soil to a depth of 6 feet or more. When moist the soil and subsoil are light brown in color. Shells and shell fragments of various forms are irregularly distributed throughout the entire profile, and in places where winds have blown away the sand, the surface is almost snow white from the presence of minute, spiral-shaped shells. The soil apparently contains an abundance of lime from this source. In some small areas associated with the Indio soils, one or more strata of brownish-gray loam or clay loam may occur below a depth of 18 inches; these range from 2 to 6 inches in thickness and are very irregular in their occurrence.

The Coachella fine sand is the most extensive soil type in the Coachella Valley area. The largest bodies, each comprising several square miles, occur northwest of Indio, west of Coachella, and along the railroad between Mecca and Mortmar. A number of other bodies occur along both the east and west sides of the valley. Rather large

areas lie northeast of Coachella, east of Mecca, and bordering the Los Angeles-Brawley Highway between Bendel and Oasis School.

This land has a billowy topography, with wind-blown hummocks and dunes 3 to 10 feet in height, and many intervening hollows or troughs. In places the surface soil is still being drifted by winds, and the soil merges by degrees into dunesand, from which it is differentiated by having lower dunes, generally a somewhat better vegetative growth, and therefore a more stable character. The drainage is good to excessive. The soil is nearly everywhere free of alkali, except a few small spots near the Salton Sea.

The typical Coachella fine sand has no present agricultural importance and none of it is under cultivation. It supports a good desert growth of creosote bush, mesquite, and other shrubs, the first-named being more common on the higher areas.

Undeveloped areas are on the market at \$15 to \$100 an acre, depending on location and topography.

The cost of leveling this soil is said to range between \$100 and \$200 an acre. Although this adds considerably to the expense of development, the soil, once leveled, would be fairly well adapted to grapes, grapefruit, and early vegetables. A number of bodies having a naturally smooth surface and others which have been leveled are outlined on the map as Coachella fine sand, smooth phase.

*Coachella fine sand, smooth phase.*—The soil material of the smooth phase is identical with that of the typical Coachella fine sand, the phase being separated on the basis of its smoother topography, lower cost of leveling, and higher values of the tracts which have been leveled. In its natural state the surface is slightly billowy, including mounds 2 or 3 feet in height which are said to entail an expense for leveling of \$50 to \$100 per acre.

This phase is much less extensive than the typical soil. Narrow strips occur east of Indio, east of Thermal, east and west of the highway from Bendel to Oasis School, southeast of Oasis, and along the railroad between Mecca and Mortmar. A number of very small bodies, mostly under cultivation, occur south of Indio.

The phase is unimportant agriculturally, only about 5 per cent being under cultivation. The principal crops are grapes, dates, alfalfa, and vegetables, including peas, beans, squash, sweet potatoes, and some onions. Yields of peas and beans range from 1 ton to 1½ tons per acre. Grapes yield 140 to 250 crates, and alfalfa 5 to 7 tons per acre.

Undeveloped tracts of this soil range in price from \$50 to \$100 an acre. Vineyards command \$300 to \$1,000 an acre, and well-developed date groves are held at \$5,000 to \$6,000 an acre.

The Coachella fine sand, smooth phase, is a little too porous to produce maximum yields of the ordinary crops. It is well suited to the production of grapefruit, early grapes, sweet potatoes, and other vegetables where early maturity is essential. The soil requires a great deal of water and thorough cultivation for best results. The plowing under of organic matter, in which the soil is deficient, has not only given increased yields but has increased the water-holding capacity of the soil and lessened the amount of water necessary to be applied.

The results of mechanical analysis of a sample of the surface soil of the typical Coachella fine sand are as follows:

*Mechanical analysis of Coachella fine sand*

Number	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
576049	Soil, 0 to 10 inches....	0.0	0.8	8.5	60.5	28.2	0.7	0.9

COACHELLA VERY FINE SAND

The surface soil of the Coachella very fine sand consists of gray or brownish-gray, highly micaceous very fine sand, 8 to 12 inches deep, with an average depth of about 10 inches. In places where the wind has reassorted the material and the finely divided mica has accumulated on the surface, the soil has a smooth, greasy feel and glistens as if mixed with fresh brass filings. The soil is low in organic matter, has a loose structure, and in places is easily drifted by winds. The subsoil is gray or brownish-gray, smooth, micaceous very fine sand or very fine sandy loam, of slightly firmer structure than the surface soil, varying from 24 to 40 inches in depth, where it passes into gray, loose, micaceous very fine sand extending to a depth of 6 feet or more. In places the profile contains one or more thin strata of gray, moderately compact silty material, but these rarely exceed 2 or 3 inches in thickness and are very irregular in occurrence. All of the materials in this soil type consist of a pepper-and-salt mixture of light and dark colored mineral particles. They contain varying quantities of small shells or shell fragments and are mildly calcareous, but there are no visible concentrations of lime carbonate or harmful quantities of other mineral salts.

The Coachella very fine sand is derived from materials carried into the valley by the Whitewater River and other streams that issue from the mountains following heavy rains. The rocks from which they were derived were for the most part granitic in character and highly micaceous. Since being deposited, the materials have been thoroughly reworked by winds; the soil now consists principally of the finer particles blown from the Coachella fine sand and carried eastward and southward by the high northwesterly winds, and piled up in dunes along the margin of the valley floor.

This type of soil is small in extent, being confined to areas between the lower parts of the valley and the higher bodies of the Coachella fine sand. The largest areas lie west of the Los Angeles-Brawley Highway west and southwest of Coachella. Other small bodies occur east of Coachella and in the vicinity of Martinez.

The surface is typically hummocky or dunelike, with mounds 3 to 10 feet high and narrow intervening troughs and hollows. The estimates given for preparing this land for irrigation range from \$50 to \$100 or more per acre, depending on the number and height of the dunes.

The typical Coachella very fine sand has no present agricultural importance, as none of it is under cultivation. The native vegeta-

tion consists of mesquite, creosote bush, and other desert shrubs, the first named sometimes attaining the size of small trees, which furnish most of the firewood used in the valley. Unimproved land of this type is held at \$100 to \$175 an acre.

Although this is an expensive soil to level, when once prepared for irrigation it would be adapted to the same crops and have the same desirable features as the smooth phase of the type.

*Coachella very fine sand, smooth phase.*—The smooth phase differs from the typical Coachella very fine sand only in having a smooth topography. The soil materials are identical, many of the areas shown on the map as the smooth phase having had a dunelike surface before being leveled for irrigation. The two conditions were differentiated on the map because of the wide difference in the cost of leveling and the greater value of the tracts already leveled.

A number of bodies, ranging from a few acres to a little less than a square mile, are scattered through the section south of Indio and southwest of Coachella. The most important bodies are at the Union High School and a few miles south and west of this point. Other small bodies occur near Bendel, Martinez, Oasis School, Oasis, and south of Point Happy. Many of these are narrow strips extending in a northwest-southeast direction and occupying an intermediate position between wind-blown soils and areas of Indio very fine sandy loam.

Both the surface and internal drainage are naturally good, and the structure is such that the soil has a higher water-holding capacity than either the Coachella fine sand or the Superstition sand. No water table was encountered on this soil in any of the 6-foot borings, and no trouble is likely to develop from alkali.

Although of small extent, this is an important soil. About 60 per cent of it is under cultivation and used for truck crops, grapes, dates, and alfalfa. The principal truck crops are onions, peas, and beans, with a small acreage of tomatoes and peppers. Onions yield 200 to 300 crates; grapes, 150 to 250 crates; peas and beans, 1 to 1½ tons; and alfalfa, 5 to 8 tons per acre. The vegetables are grown as winter crops, beans being harvested in November and December, peas from January until the middle of March, and tomatoes and peppers early in May.

Undeveloped land of this soil can be bought for \$150 to \$175 an acre. There are not many developed tracts on the market. Well-cared-for vineyards are held at \$1,000 or more an acre, and date orchards of good varieties are held at considerably higher figures.

The Coachella very fine sand, smooth phase, is an excellent soil well adapted to all of the special crops being grown in the valley. It is especially well suited to early vegetables, being somewhat more productive than the fine sand of the series. The ease with which it can be cultivated and its freedom from alkali add greatly to its value. It requires somewhat more water than the soils of heavier texture, but the plowing under of alfalfa or other leguminous crops would increase its retentiveness of moisture, besides lessening the tendency to blow.

The following table gives the results of mechanical analysis of a sample of the soil of the typical Coachella very fine sand:

*Mechanical analysis of Coachella very fine sand*

Number	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
576051	Soil, 0 to 10 inches....	0.0	0.5	1.8	23.5	65.8	1.7	1.3

#### DUNESAND

Dunesand consists of light-brown or grayish-brown, loose, incoherent sands of various textures, occurring in dunes usually too large to be economically leveled for irrigation. West of Indio the sand ranges from medium to very fine in texture and usually shows but little change to a depth of 6 feet or more. In other localities the surface soil is somewhat coarser. This land resembles the Coachella fine sand, but differs from it in having larger dunes or in being more barren of vegetation and having a greater tendency to drift. Most of the dunes range from 10 to 30 feet in height, although bordering the wash of the Whitewater River west of Indian Wells there is a strip of dunes varying from 40 to 60 feet or more in height. The scattering growth of creosote bush and low mesquite is insufficient to protect the surface from blowing, and under the influence of the strong northwesterly winds the dunes are creeping to the south and east, the small ones sometimes moving several feet as the result of a single storm. In the more northern areas the dunes are lower and the surface is similar to that of the Coachella fine sand. Although the topography here is more favorable for leveling, the surface has less vegetation and the soil is more readily shifted by winds.

Dunesand is extensively developed in the northwestern part of the survey. The largest bodies occur bordering the north side of Whitewater River from Point Happy westward to several miles beyond the limits of the survey, and extending southward from this stream to southeast of Point Happy. Other bodies are found near the northwestern corner of the area surveyed, along the railroad northwest of Indio, and scattered through the areas of Coachella fine sand west of Coachella.

As mapped, the dunesand includes small undifferentiated patches of Coachella fine sand. Some of these may eventually be leveled for irrigation, but in general the rough topography and tendency to drift make the dunesand unfitted for agricultural use.

#### ROUGH BROKEN AND STONY LAND

Rough broken and stony land comprises mountainous or hilly areas whose slopes are too steep and stony or too rough and broken for agricultural use. The boundaries of the survey have been so drawn as to include marginal strips of these materials along the east and west sides.

The area bordering the valley on the west is the eastern edge of the Santa Rosa Mountains, and the surface is extremely rough and

ugged. Frequently within one-half mile the elevation increases 1,000 to 1,500 feet, and elevations of 4,000 to 6,000 feet are attained within a few miles of the valley. The material is mainly granite and consists principally of rock outcrop with so thin a soil covering that it is practically bare of plant life.

The bodies mapped on the east side of the valley are lower and less stony. They are hardly mountainous; they consist, rather, of minutely dissected foothills which merge into mountains 1 to 3 miles from the valley. In places on the lower slopes the soil is comparatively free of stones and is similar to the land mapped in other parts of the State as rough, broken land. Instead of massive granite, the material is formed from old water-laid deposits consisting of purplish clays and soft, light-colored, coarse sandstone and conglomerates in various stages of hardening. These areas are as bare of vegetation as the mountains on the west and are equally valueless for agriculture.

#### IRRIGATION AND DRAINAGE

The average rainfall is so slight in the Coachella Valley that it is practically disregarded, and the sole dependence for water in growing crops is placed in irrigation. The source of this supply lies principally in the rainfall and the melting snows on the high mountain peaks at the northwestern end of the valley. These waters reach the valley through the Whitewater River and a number of tributary streams, but long before they reach the area surveyed they sink into the sands and thence find their way as subterranean waters to the Salton Basin. Therefore all the water used for irrigation is derived from wells. These are of two kinds, artesian or flowing wells, and those which must be pumped. During the first few years of development nearly all of the wells flowed a sufficient volume for irrigation, but with the increase in the number of wells the water table was soon lowered and the pressure so far reduced that many of the wells around the margin of the artesian area ceased to flow, or the flow was so decreased that pumping had to be resorted to. It is said that the water table is still gradually being lowered and from time to time some of the pumps have to be lowered in the wells. In 1900 flowing wells were obtained at Indio, but now the upper limits of the artesian belt are about at Coachella. According to local information, the perimeter of the artesian belt, in the area surveyed, has decreased from about 70 to 52 miles. The depth of wells varies from 200 to 1,500 feet, the greater number being around either 500 or 800 feet in depth. Above the artesian district the water rises in the wells to within 10 to 30 feet of the surface. The water used is of exceptional purity, containing only 12 to 25 parts of saline matter per 100,000.<sup>9</sup>

It is estimated that there are about 11,000 acres in the valley under irrigation. The agriculture is characterized by continual cropping, so that irrigation is necessary during every month in the year. This, combined with an unusually high rate of evaporation and the fact that the soils of many of the irrigated areas are sandy and

<sup>9</sup> Water Supply Paper 225, Ground Waters of the Indio Region, California, U. S. Geological Survey.

porous, necessitates the use of larger quantities of water in the Coachella Valley than are usually applied in other irrigated sections. The average for the valley is locally reported to be about 5 acre-feet. Many date groves are receiving as much as 8 acre-feet a year, alfalfa 7 to 10 acre-feet a year, onions about 5 acre-feet, and grapes are given about 2 acre-feet a year. During the summer water is applied more frequently than in winter. The furrow system of distribution is used for most crops, but with dates the water is usually run into a basin around each individual palm. Practically all of the pumping is done by electricity. The cost varies considerably in different parts of the valley owing to the different lifts, being greatest at the outer margins of the valley and diminishing toward the artesian section.

The lower part of the Coachella Valley is in need of drainage. When the underground waters reach the soils upon the floor of the valley the rate of percolation is sharply checked by the finer-textured materials and a considerable part of the water is held at relatively shallow depths. Evaporation from the surface of the soil is exceedingly high, owing to the high temperatures and low humidity throughout the greater part of the year, and with the removal of the water, the alkali salts remain as accumulations on or near the surface. Thus all of the poorly drained soils in the Coachella Valley are more or less affected by alkali.

The poorest drained area is around the shore of Salton Sea. For about one-fourth mile back from the sea the water table is only a few inches below the surface. Along the east and west sides of the sea the water table deepens rapidly, as there is a considerable increase in the elevation of the land toward the margins of the valley. Northward, however, the slope is much less and the ground-water plane gradually deepens to about 5 or 6 feet near Thermal. Between the Salton Sea and Mecca the poorly drained area averages about 5 miles in width; at Thermal, about 4 miles in width; east of Coachella, about 2 miles in width, from which point northward it gradually narrows down until it terminates in the well-drained sandy areas about 5 miles northwest of Indio. Branching off from this body west of Mecca is a low depression about 1 mile in width extending westward across the Los Angeles-Brawley Highway about one-half mile north of Bendel. Over parts of this the free ground water is encountered only a few inches beneath the surface, and alkali is abundant in the form of surface crusts. The poorly drained areas are coextensive with the areas strongly affected by alkali and cover a total of 57.3 square miles. They are confined almost entirely to the trough or lower part of the valley.

Excepting a few small patches elsewhere throughout the area surveyed, the remainder of the valley has good surface and internal drainage. Only short distances from poorly drained areas the water table stands 20 feet or more below the surface, and since the soils are mainly sandy with porous strata in the subsoils and the surface has a fall of 20 feet or more per mile, the rest of the area surveyed should have but little drainage trouble, providing ordinary care is used in irrigation.

Reclaiming the poorly drained land will undoubtedly call for the construction of a deep drainage ditch extending lengthwise through the trough of the valley, and probably a number of other deep ditches



whose location can be determined only after careful surveys have been made. Until recently considerable areas in the vicinity of Indio and Coachella were subject to flooding following unusually hard storms in the mountains at the upper end of the valley, but these infrequent overflows are now confined within a levee bordering a shallow ditch which conducts the water down the trough of the valley to the Salton Sea. The drainage and alkali problems in the Coachella Valley are practically one and the same. Any method of permanently correcting the alkali calls first for improving the conditions of drainage. There are some small tracts that can be drained by individual effort, but the problem as a whole is of such magnitude that cooperative action is necessary in order to obtain adequate outlets and reduce the cost per acre.

#### ALKALI

The alkali conditions in the Coachella Valley are similar to those existing in the Imperial Valley on the south, and the same methods are used in mapping.<sup>10</sup>

In the process of soil formation through the disintegration and decomposition of rocks, a variety of mineral salts and chemical compounds are formed. Some of these go readily into solution in water; others are practically insoluble. Under normal conditions of rainfall the more soluble materials are washed out, and where the rainfall is excessive, the leached soils, low in lime and other valuable constituents, predominate. Under arid conditions, however, such as prevail in the Coachella Valley, the compounds are rarely entirely dissolved, or if dissolved, are soon recrystallized from solution, with the result that they are not removed through the normal processes of drainage but remain in various forms within the soil minerals.

In the chemical sense, "alkali" is a substance which neutralizes acids, but agriculturally the term "alkali" is used to designate any of the common mineral salts, regardless of chemical reaction, when occurring in quantities sufficient to be injurious to crops.

The most common alkali or soluble mineral salts affecting the soils of the Coachella Valley are sodium chloride (common salt), sodium sulphate (Glauber's salt), sodium bicarbonate (baking soda), and calcium chloride. These are all known as "white alkali." Sodium carbonate, which under field conditions is the most harmful, has been found in a number of localities. This salt is a true alkali and because of its corrosive action on organic matter in the presence of moisture it produces a dark-brown or black stain on the surface of the soil and is therefore commonly known as "black alkali."

In addition to the above-named salts, calcium carbonate (lime) is abundant in all the soils of the valley. Although chemically alkaline, agriculturally this material is not considered an alkali, since normally it is rather feebly soluble and not injurious to crops, and under certain conditions it is highly desirable and even essential to plant growth. Practically all the soils of the Coachella Valley contain great quantities of small shells and shell fragments

<sup>10</sup> Soil Survey of the Brawley Area, California, Field Operations of the Bureau of Soils, 1920. A comprehensive study of the alkali problem is found in "Soil Alkali," by F. S. Harris, New York.

which provide a ready source of lime for the use of plants, and the application of lime from other sources as a fertilizer is not likely to be necessary.

Sodium chloride, or common salt, is a common alkali salt in the soils of the Coachella Valley. Strong concentrations occur over several thousand acres around the shore of Salton Sea and extending in a narrow strip from the sea northward to a point about 5 miles northwest of Indio. At the lowest point in the basin, now occupied by the Salton Sea, works were operated for the commercial production of salt for a number of years before the inflow of the Colorado River.

The degree of harmfulness which alkali salts exert on plants depends upon a number of factors, the most important of which are the kind, quantity, and distribution of the salts; the moisture conditions of the soil, and, to some extent, the kind of crops grown. The influence of each of these factors is modified by the presence of other factors and by the intensity with which they operate, and therefore it is not possible to make other than very general statements concerning the effects of alkali upon the growth and production of cultivated crops. If it were possible to maintain uniform distribution of the alkali salts throughout the soil, it would be possible to predict with considerable certainty the results of the cultivation of such land. But, unfortunately, the distribution of alkali salts is not and does not remain uniform, and the vertical distribution of such materials is of very great importance. A concentration of alkali salts at the surface of the soil may be sufficient to prevent the growth of all forms of vegetation, but with the same concentration localized at a depth of 5 or 6 feet below the surface, there would be little interference with the growth of shallow-rooted crops.

Among the commercially grown plants which are least affected by alkali are the date palm, rice, and Rhodes grass. It has been demonstrated that the date palm, when once established in an alkali soil, will grow, provided the roots have access to a soil layer containing not more than 1 per cent of salts. Considering the great expense of developing a date grove and its subsequent high value, however, it is doubtful if lands strong in alkali should be used for this crop so long as better grades of soil are available at reasonable prices. Rhodes grass has been grown on soils strongly affected with alkali in the Imperial Valley, and it is probable that some of the alkali lands in the Coachella Valley could be used successfully in growing this crop.

In determining the alkali content of the soils of the area, as indicated upon the accompanying alkali map, borings were made and the content of alkali, based upon the percentage of salts in the air-dry soil, was determined by the use of the electrolytic bridge especially devised for this purpose. The location where samples were taken and the percentage of salt content is given on the map. The quantity of alkali present appears upon the map in the form of a fraction, the number above the line expressing the percentage of salts within the surface foot, and the number below the line gives the average salt content to a depth of 6 feet.

Differentiation of the various grades of alkali as indicated upon the map, however, is not based entirely upon the percentages of salts as determined, but partly upon distribution of the salts, the surface appearance, and the general condition of crops. In undeveloped sections the native vegetation and general soil appearances were frequently useful in indicating the prevailing alkali condition or grade of concentration.

The map as constructed shows four grades of alkali conditions—alkali-free areas, slightly affected areas, moderately affected areas, and strongly affected areas. The first grade includes those areas whose total salt content is less than two-tenths of 1 per cent, so distributed as to be noninjurious to crops. The second grade includes those lands whose total salt content is greater than that of grade one but less than six-tenths of 1 per cent, so distributed as to show little or no appreciable effect on crops. The third grade comprises those areas whose content of total salts is less than 2 per cent, but so distributed as to show a visible effect on crops. The fourth grade, or strongly affected areas, includes those lands having more than 2 per cent of salts, or smaller quantities so distributed as to preclude profitable cultivation to ordinary crops.

For all practical purposes the first grade of land may be designated as alkali free. This grade is extensive and includes practically all of the gravelly and stony fans and slopes along the margins of the valley, practically all of the sandy soils of the Coachella series, and large areas of dunesand in the northwestern part of the area surveyed. This grade of land is confined primarily to soils of light texture, although there are a few alkali-free areas of Indio loam and of the silty phase of the Indio clay loam west of Indio. No appreciable damage is being done by alkali on lands of this grade and alkali troubles are not likely to occur.

The second grade, or slightly affected land, is inextensive and is confined principally to medium and light textured soils near the outer margin of the floor of the valley. The largest body, consisting of the Indio loam and silty phase of the Indio clay loam borders the railroad between Indio and Coachella. From the agricultural standpoint most of these areas may be considered as containing only a trace of alkali, since the total salt content is frequently around two-tenths of 1 per cent. Brown discolorations and slight surface concentrations are common on the surface, although as yet there have been apparently no injurious effects on plants. This grade of land contains soils with a maximum salt content up to six-tenths of 1 per cent. Where the content approaches the maximum for this grade and no effects are seen on crops, the salts are almost invariably confined to the subsoils, the surface soils being comparatively free. In their present condition the soils of this grade compare favorably with soils which are alkali free, and so long as the salts are confined to the subsoils no danger of alkali need be feared. However, improper irrigation with inadequate provision for underdrainage may bring the salts to the surface, and should a considerable proportion of them accumulate within the feeding zone of plant roots, serious damage might be expected to result.

The third grade mapped includes moderately affected areas or those lands on which it is plainly evident that alkali is affecting

crops. Throughout areas of this grade of concentration the crops are usually spotted, yields are lower, and usually there are indications of alkali upon the surface. This grade includes a wide range in total salt content, from small quantities concentrated on the surface up to a maximum of 2 per cent. Over a large proportion of the lands of this grade the total content of alkali in the 6-foot profile is comparatively low, many areas showing an average content of less than six-tenths of 1 per cent, but with a high concentration near the surface. The lands of this grade are inextensive and are confined principally to narrow strips occupying an intermediate position between the better grades of land and the strongly affected areas. One of the largest areas, ranging from one-half to three-fourths mile in width and about 11 miles in length, occurs on the east side of the railroad from about  $1\frac{1}{2}$  miles south of Coachella to about 5 miles northwest of Indio. A number of other small bodies lie east of the railroad between Coachella and Mecca.

The fourth grade of concentration includes strongly affected areas or lands on which profitable yields of the ordinary crops can not be produced under present conditions. Usually the lands of this grade contain a large percentage of salts, extensive bodies being found around the shore of the Salton Sea and extending northward through the lower part of the valley, in which the total salt content is 1 to 2 per cent, while considerably more than 3 per cent is concentrated near the surface. Throughout the greater part of this grade of concentration the surface is covered with a brittle alkali crust one-fourth to one-half inch in thickness, or the immediate surface is flocculated or unnaturally loose and fluffy. Frequently the soil contains a quantity of salt crystals, and in places the surface is white with salt. Not always is this grade of salt accumulation determined by a large average salt content within the 6-foot section, but is frequently the result of a high water table, which has caused a high concentration of salts upon or near the surface. This condition is confined to the trough, or lower part, of the valley. Practically all of the soils of the Woodrow series, much of the Indio clay loam and clay, and small bodies of Indio loam and Indio clay loam, silty phase, are in this class. The lighter-textured soils, because of their more general occurrence in the better-drained sections of the valley, are rarely in the strongly affected class. Little attempt is made to farm these lands, a number of fields formerly cultivated being now abandoned. At the present time probably less than one-half of 1 per cent of the land in this grade is being cropped. In some instances dates have been planted, but the alkali was too strong for even this resistant plant, and most of the palms are dead. West of Thermal, where the grade is determined by a high surface concentration, there is a fairly thrifty date grove, the palms apparently having adapted their root systems to a feeding zone containing only a moderate quantity of salts.

A large area in the Coachella Valley is strongly affected by alkali. Beginning as a narrow strip north of Indio, the strongly affected area extends southward a little to the east of Indio and Coachella, below which it gradually widens to the Salton Sea. From Thermal northward it lies principally on the east side of the railroad; south of this point it is mainly on the west or south side of the track.

Practically all of this area is unsuited to the cultivation of ordinary crops. As the Salton Sea recedes through evaporation additional land is exposed, and as none of this is being reclaimed at the present time the total area of the strongly affected soils is increasing.

The following table gives the acreage and proportionate extent of each of the four grades of lands mapped in the Coachella Valley area:

*Classification of lands on the basis of alkali content*

Alkali-free areas <sup>1</sup>		Slightly affected areas		Moderately affected areas		Strongly affected areas	
<i>Acres</i>	<i>Per cent</i>	<i>Acres</i>	<i>Per cent</i>	<i>Acres</i>	<i>Per cent</i>	<i>Acres</i>	<i>Per cent</i>
148,928	67.6	18,560	8.4	16,000	7.3	36,672	16.7

<sup>1</sup> Including 77,504 acres of rough broken and stony land and gravelly and stony soils.

At the present time all of the lower-lying parts of the strongly affected alkali lands in the valley have a high water table. The depth to water varies from a few inches near the Salton Sea to about 6 feet near Thermal. Any increase in the acreage of the strongly affected lands will depend upon action of the water table. Should continued increase in the irrigated acreage tend to raise the water table in the lower parts of the valley, an increase in the acreage of the strongly affected alkali lands may be expected. So long as pumping must be relied upon to furnish water for irrigation, it is not likely that enough will be applied to raise the general level of the water table. In case the proposed All-American Canal bringing water from the Colorado River is completed, it would be necessary to take precautions in the way of drainage in order to forestall a possible rise in the water table and the resulting increase in the acreage of strongly affected lands.

In the reclamation of alkali lands the most practical and satisfactory method is to wash out the salts by drainage and leaching, thus removing them permanently from the feeding zone of plants. The feasibility of this depends upon a number of factors, among the most important of which are the water supply, the availability of drainage outlets, the porosity of the soils, and the character of the salts. At the present time the available supply of water is too limited and expensive to go far toward reclaiming the alkali lands of the valley. It is probable, therefore, that most of the strongly affected alkali lands will not be reclaimed until a more abundant and cheaper supply of water is provided. It will not be feasible to drain the lowest part of the basin now occupied by the Salton Sea, since it lies 250 to 280 feet below sea level and has no drainage outlet. It is probable also that for many years there will be a body of 5,000 acres or more of Woodrow soils extending northwestward from the sea on which reclamation will be impracticable on account of the difficulty of obtaining outlets and the presence of a heavy clay or relatively impervious layer in the subsoil. Throughout the remainder of the affected areas a fall of 4 to 20 feet per mile is obtainable and the subsoils almost invariably contain one or more strata of sandy material. The cost, however, would undoubtedly be high, and the problem is of such magnitude that concerted action would be necessary to handle it.

## SUMMARY

The Coachella Valley area is situated in the southern part of Riverside County, in the southern part of California. Indio, the principal town, is 130 miles southeast of Los Angeles. The valley is a low, desert basin, the floor of which lies from 250 feet below sea level to about 100 feet above. The lower part is occupied by the Salton Sea, which separates it from the Imperial Valley on the south. On the other three sides the valley is closely hemmed in by mountains. The lower part is poorly drained and is of little value because of alkali. The outer margins consist of stony or gravelly slopes of low value. Between these two conditions the soils are productive and of unusually high value. The area contains 344 square miles, or 220,160 acres.

The settlement is confined mainly to the vicinity of Indio and Coachella, the principal towns. The population of the area is about 3,700. The main line of the Southern Pacific Railroad and a paved highway traverse the length of the valley.

The climate is arid and is well adapted to the growing of winter vegetables under irrigation. Frosts and destructive winds are rare, while snow, hail, and fog are practically unknown. The summers are long and hot, a maximum of 118° F. or more having been recorded for every month from May to September, inclusive. The low relative humidity lessens the oppressiveness of the heat. The annual rainfall for the entire valley is about 3 inches.

Most of the agriculture in the area is less than 25 years old. At the present time it consists of the growing of cotton, winter truck crops, and fruits for sale; the raising of alfalfa, milo, and grain hay for feeding work animals; the raising of poultry and poultry products for sale and for home use; dairying for local markets; and the raising for home use of nearly all of the food commodities required on the farm.

The largest acreages are devoted to cotton, onions, and grapes. The valley is the principal date-producing section in America. The grapes come on the market the first of July, when there is no competition from other sections. Grapefruit is marketed before the holidays and commands a premium in price.

Most of the improved farms range from 20 to 40 acres in size, although there are many vineyards and date groves containing only 5 to 20 acres. The Southern Pacific Railroad Co. owns a large proportion of the valley. Only about 5 per cent of the area surveyed is under cultivation.

General farm lands under irrigation sell for \$200 to \$400 an acre. Vineyards are held at \$1,000 or more an acre, grapefruit orchards at \$1,500 to \$2,000 an acre, and date groves \$4,000 to \$6,000 or more an acre. Good unimproved land suitable for irrigation can be had for \$100 to \$150 an acre.

The agriculture of the Coachella Valley is highly specialized and calls for considerable skill and rather large expenditures. There are excellent opportunities for extending the growing of dates, grapefruit, and grapes.

The soils of the area have been derived from water-laid unconsolidated materials carried into the valley by water and later redistrib-

uted to some extent by water or winds. They are all deficient in organic matter, highly micaceous, rich in soluble materials, including lime carbonate, light colored throughout the entire profile, and very irregularly stratified.

The soils on the valley floor include the Indio, Coachella, and Woodrow series; on the sloping fans, the Superstition series. Rather large areas of dunesand occur in the north end of the area, and strips of rough broken and stony land border the east and west sides.

The Indio series comprises five soil types and one phase. The Indio clay loam and clay are, for the most part, strongly affected by alkali and are of little present value. The Indio very fine sandy loam, loam, and silty phase of the clay loam are highly productive and adapted to all of the crops of the valley.

The Coachella soils include the wind-blown sandy materials of fine sand and very fine sand texture. They are easily cultivated, moderately productive, and well adapted to truck crops or any products in which early maturity is an important factor.

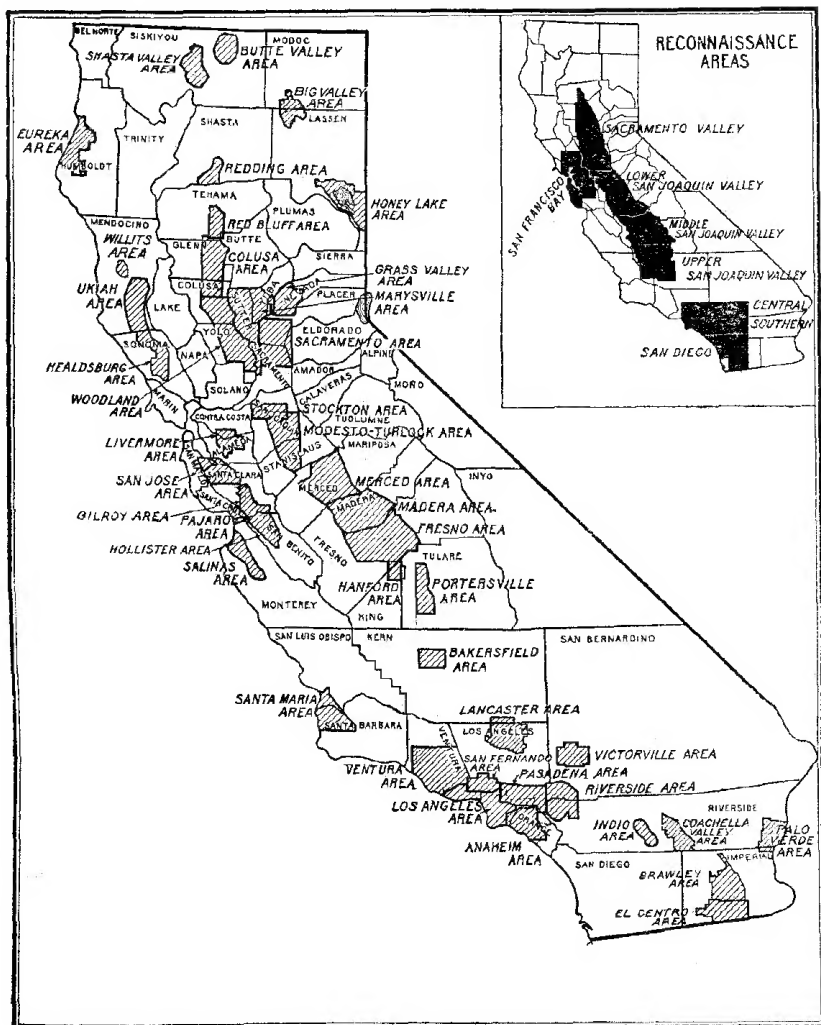
The Woodrow soils include the lake-laid deposits along the shore of Salton Sea. They are characterized by one or more layers of gray, plastic, relatively impervious clay. They are usually compact, poorly drained, and high in alkali. These soils are mainly undeveloped and in their present condition are valueless for agriculture.

The Superstition series includes principally the stony and gravelly soils of the alluvial fans and slopes between the valley floor and the mountains. Five types of soil are mapped. Only one of these, the sand member, is cultivated, the others being gravelly or stony and porous, and without means of irrigation.

About 11,000 acres of land are under irrigation in the Coachella Valley at the present time (1923). The water is obtained entirely from wells. In the lower portions of the valley the wells are artesian, whereas in the higher-lying parts the water is brought to the surface by pumping. The water is of excellent quality. The average duty of water is said to be about 5 acre-feet per year.

The greater part of the land in the lower part of the valley is in need of drainage to correct the present high water table and to remove the excess of alkali salts. The absence of any deep, natural drainage courses makes drainage impracticable for the individual farmer, and the construction of an efficient drainage system can be obtained only through community action.

Alkali is generally present in the soils in the lower part of the valley. Over considerable areas the amount and vertical distribution of the soluble salts is such that crop yields are but slightly affected, but there are also considerable areas where the quantity of alkali is so large that the growth of cultivated crops is out of the question. Excessive quantities of alkali can be removed only through adequate underground drainage and leaching.



Areas surveyed in California, shown by shading



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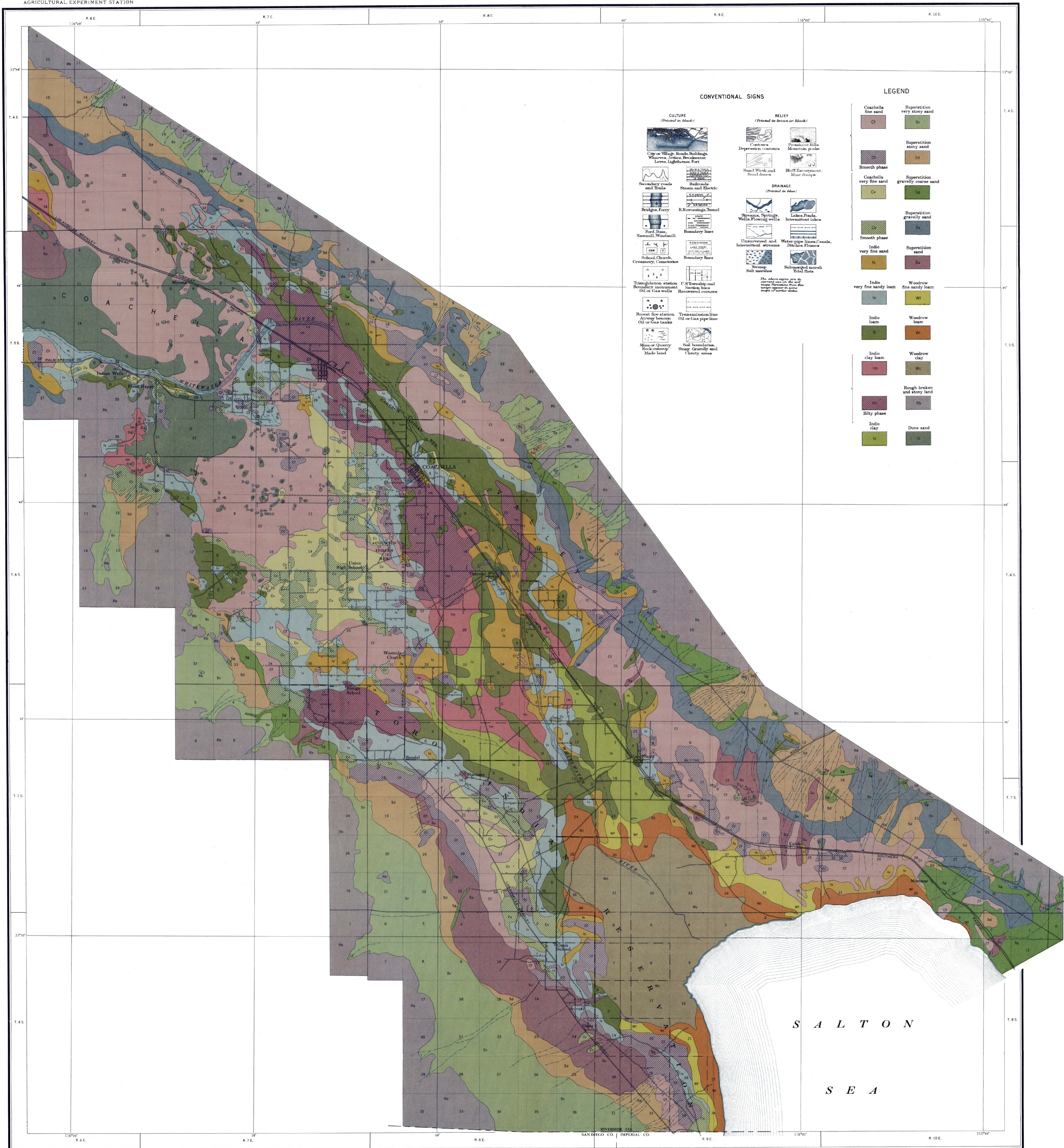
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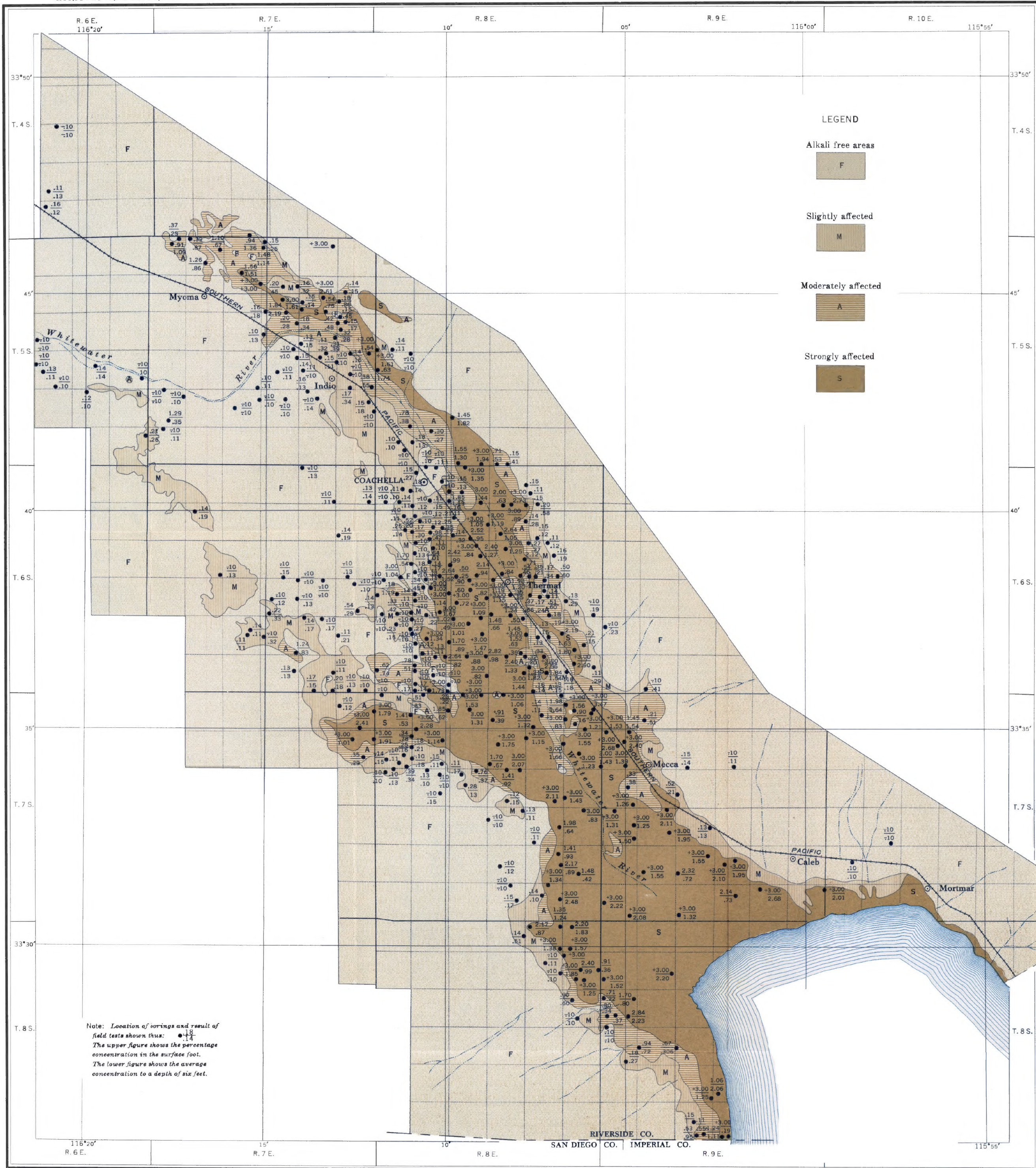






# ALKALI MAP

CALIFORNIA  
COACHELLA VALLEY SHEET



Alkali surveyed by A. E. Kocher, in charge,  
and W. G. Harper

WILLIAMS & HEINTZ CO. WASH., D.C.

Field Operations  
Bureau of Soils  
1923